

SEX IN MAN AND ANIMALS

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WITH A PREFACE

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PREFACE

BY

PROFESSOR JULIAN S. HUXLEY

ONE of the leading characteristics of my friend Mr. Baker, manifested equally when I first knew him as my pupil and in later years as my colleague, has always been to try to get at the essential simplicities of things, to strip away unnecessary details, unwanted complexities of terminology, and to obtain a straightforward common-sense picture of whatever mechanism or process he has been investigating. This attitude is not always to be found in men of science. There are some who delight in detail, some who revel in the most complicated terminology, provided only it be unfamiliar and therefore impressive to others, some again who are more interested in unravelling the special complexity of the particular case than in tearing out the general principle at the heart of many cases.

This desire for plain simplicity and downrightness characterizes his exposition as well as his method of intellectual attack ; and it is this, I think, which the reader will especially notice and welcome in the present volume.

It is, of course, true that there are problems which are not simple ; and that even processes whose underlying principles are simple may in actual fact be on the highest levels of complexity. It is, however, also true that for the diffusion of new knowledge among the general public it is much more important to aim at intelligible presentation of principle than to attempt meticulous accuracy or elaborate detail ; and that, in any case, as the history of science has again and again demonstrated, the actual complexity of a given process can only be properly understood by taking it to pieces, so to speak, finding the underlying principles, and then putting it together again by a synthesis of these.

It is for this reason, that it is written in the simplest

language and presented in the most straightforward way, that I welcome this little book of Mr. Baker's on the subject of sex, and wish it many readers.

Sex has been called one of the great mysteries, a mystery equal to that of life itself. That description was justified fifty or even twenty-five years ago; to-day it is so no longer. In the last quarter of a century Biology has let the light of day into this dark chamber in her house; if we do not yet understand all the details clearly, it is certainly true that the main lines are now plain to see.

We now know, to start with, what processes are observed to occur in sexual reproduction—something completely hidden not only from the ancients but from the moderns up till the latter half of the nineteenth century.

We know what is the significance of sexual reproduction in regard to heredity—an advance made possible by Mendel's great discoveries and the subsequent intensive work along Mendelian lines. We can hazard a very reasonable guess as to the value of sex in evolution, even if its first origins remain more problematical. We know how the sex of higher animals and of man himself is normally determined—through the agency of one of the chromosomes, those bodies whose name the man in the street will have to incorporate in his vocabulary, since it is they that make us what we are. We know how our sexual characters, once sex is determined, are maintained—through the agency of special substances or hormones circulating in the blood.

Through this knowledge we are introduced to the not too remote possibility of influencing sex-characters and controlling sex-determination—a possibility as alarming as stimulating in the vistas which it conjures up. We are made far better able to understand many sexual aberrations and abnormalities, and to see not only that many things we called crimes may really be diseases, but also that, for society with its present knowledge, the fact of the existence of many of such diseases is really a crime.

In short, we are beginning to understand the principles underlying the important facts of biology, beginning to see how, through that understanding, we may arrive at

the control which will make us more masters of our fate than slaves of unknown power.

I welcome the book too because it is a good thing that the facts of sex should be frankly and rationally discussed. Sex is at present the greatest of the tabus which have survived from the age of tabu through which all societies seem to have passed; and it is not good that a subject of such overwhelming importance alike for the individual and for the race should be tabu.

I am not one of those optimists who believe that to tell a boy or girl the facts of sex is to ensure that he or she shall not be troubled by sex-problems with all their difficulties and darkness. Nor do I associate myself with those who, more enthusiastic than either sensible or seemly, appear to think that the only alternative to a tabu on sex is to discuss it in fullest detail at every opportunity.

Sex will always bring its difficulties to the difficult age of adolescence; it will always continue to touch the deepest and most intimate parts of our nature so that right-minded people will continue to demand for it that privacy and respect which we demand for everything personal and sacred. But it cannot be doubted that proper knowledge and a frank attitude to the subject will diminish the cruelty of the inevitable difficulties; that much of what is ugly and abnormal in life comes from unnecessary self-repression; that reverence is not incompatible with free discussion, and that to associate a tabu with whatever we feel sacred is not necessary, but, on the contrary, the mark of a primitive society and an unenancipated mind.

There are not wanting signs that the general public are realizing these facts, and striving after this way of thinking. We do indeed seem to be on the threshold of a new era, characterized by an attitude of mind which may be called scientific humanism.

For such a state of affairs to be realized, it is necessary that science be related to human life, that knowledge of science be widely diffused among the general public. May Mr. Baker's book contribute, as it deserves, to this end.

J.S.H.

AUTHOR'S PREFACE

In preparing this book I have adhered as far as possible to the following five principles :

- (1) *That the subject should be presented in such a way as to render it equally suitable for the general public on the one hand, and for biological and medical students on the other.* In my attempt to avoid pedantry, I have written a little figuratively in places, trusting to the reader's ability to recognize a figurative remark and to treat it as such. For instance, when I write to the effect that in the course of evolution a certain character has been produced for a certain purpose, I take it for granted that this teleological manner of speech will not be interpreted as indicating supernatural interference.
- (2) *That the reader should be introduced directly to modern theories without having first to wade through accounts of obsolete hypotheses.**
- (3) *That the subject should not be limited to its biological aspect.* There is so much specialization within a science nowadays, with corresponding ignorance of other sciences, that everything should be done to bring more than one science within the covers of a single book. I have therefore touched upon the anthropological and psychological aspects of the subject.
- (4) *That photographs¹ and accurate drawings of actual specimens should be given wherever possible rather than diagrams.*
- (5) *That the figures should all be original.†*

* In Chapter II I make a notable departure from this principle for reasons which I state, and in Chapter IX I touch upon some popular misconceptions with regard to the control of the sex ratio.

† The only figure which was not specially drawn for this book is Fig. 17, which was one of the illustrations to a paper by myself in the *British Journal of Experimental Biology*. I redrew and slightly modified it for this book by kind permission of the Editor, Dr. F. A. E. Crew.

I wish to thank my former tutor, Prof. Julian S. Huxley, for his great kindness in reading the typescript of the whole of this book and making numerous suggestions for its improvement which have added very greatly to any value which it might otherwise have possessed. He has given up a considerable amount of his valuable time to giving advice which no one else could or would have given.

I am also indebted to Prof. E. S. Goodrich for very kindly reading the typescript and pointing out a number of errors, and also for allowing me to prepare figures from specimens in the Department of Zoology and Comparative Anatomy at Oxford.*

It was at my wife's suggestion that I started to write this book, and I cannot exaggerate the benefit that I have derived from her constant encouragement and advice. She has revised the whole book from the standpoint of a reader with no special knowledge of biology, and has insisted upon the alteration of all obscure points.

* This applies to Figs. 1, 4 (in part), 5, 6, 7, 8, 9, and 12.

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SEX IN MAN AND ANIMALS

CHAPTER I

THE BIOLOGICAL SIGNIFICANCE OF SEXUAL REPRODUCTION

INTRODUCTION

It is scarcely an exaggeration to say that not a moment of our lives is unaffected by any of the varied manifestations of sexuality. One has only to try to imagine everyday life in a community of sexless individuals to realize its enormous importance. Not only is our conscious existence modified, for recent advances in psychology have shown that sex has a profound influence on the subconscious mind. It is very probable that sublimation of the sexual instinct has helped to give the world its treasures of art and music. Fiction it has affected more directly, for there is little that does not centre on a sexual theme. If we turn from mankind to the whole world of animate nature, we find that there are very few organisms indeed, with the exception of the bacteria, that are wholly non-sexual in their mode of reproduction.

Although these platitudes are the common property of every man and woman, there are very few who take the trouble to seek their interpretation. The human mind has a wonderful faculty for taking things for granted, whether

natural phenomena or artificial laws or incredible creeds are concerned. What benefit do living organisms gain by reproducing sexually rather than asexually? If we assume *sufficient variation and the survival of the fittest*, we can interpret—incompletely, it is true—the evolution of any structure or mode of life that is beneficial to the organism concerned. But at first sight sexuality is inexplicable, because it is so difficult to see in what way it is beneficial. For the benefit of those whose curiosity has been aroused on this subject, I will try in this chapter to explain as simply as possible what is known and what is surmised about its significance. But before we can begin, it is necessary, that we should understand what advantages accrue to organisms from reproduction of any sort. The power of growth is one of the most salient characteristics of living matter. Why should not organisms merely grow larger and larger without reproducing at all?

THE SIGNIFICANCE OF REPRODUCTION

As an organism grows, it becomes increasingly difficult for it to perform certain functions which are necessary for life. The reason is that the bulk or volume of the animal increases more rapidly than its surface. Now many of the lower animals depend upon their whole surface to obtain oxygen and to remove poisonous waste-products. The larger the surface relatively to the bulk of the body, the more readily are these functions performed. The result is that growth renders them more and more difficult until finally a stage would be reached at which the interior of the



FIG. 1. The thigh-bone of a chevrotain (left) and of an elk (right), the latter reduced so as to appear of the same length as the former. (Photos by Mr. A. Robinson and Mr. W. R. Rose)

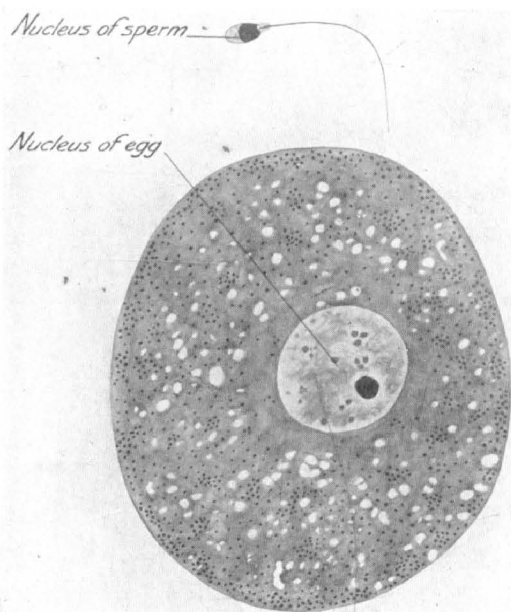


FIG. 2. The sperm and the egg of the rabbit, drawn at the same magnification.

body would begin to decompose through the accumulation of waste products.

In the higher animals these circumstances are less pressing, owing to the presence of efficient respiratory and excretory systems ; but other difficulties arise which make continued growth unfeasible. A skeleton must be produced to support the growing frame ; and if this skeleton is to remain as strong, it must grow faster than the rest of the body. The reason for this is that if an animal doubles its length and remains of the same shape, its weight is increased to eight times its original weight ; and therefore the area of a cross-section of each supporting bone must increase to eight times what it originally was, *i.e.*, its diameter must be increased fourfold. In other words, when an animal's length is doubled, its bones have to become not twice as thick, but four times as thick. It will be readily seen that this process carried to its logical conclusion would result in an animal becoming a mass of bones to the virtual extinction, relatively, of the various vital organs. The phenomenon is seen when one compares the thigh bone of a chevrotain (a small ungulate not unlike a deer) with that of an elk (Fig. 1). The photo of the thigh bone of the elk has been reduced so as to make it appear of the same length as that of the chevrotain. The great thickness of the elk's bone compared with that of the chevrotain is well seen.

Again, the chances of finding sufficient food are greatly increased by multiplication accompanied by dispersal, and this is perhaps one of the greatest benefits conferred by the power to reproduce. Wide dispersal renders the large number of individuals produced by reproduction unlikely

each and all to suffer from some accident which, without reproduction, could easily destroy the one individual, and thus the whole race.

There are other factors which limit increase of growth, and the study of the limiting factors in each case is a very large question. But sufficient has been said to show that indefinite growth is impossible, and some alternative must be forthcoming.

The obvious alternative is division into two parts, and this is what occurs in a large number of the more lowly organisms as one method of reproduction. It is confined to the more lowly organisms because the higher ones are so highly specialized that one half would be quite unable to persist without the other, and would be unable to regenerate the missing parts so as to reconstruct a new whole. So the method adopted is to separate off small portions of its body, the loss of which does not inconvenience it; and these small portions, never having been modified to perform special functions in the body of their parent, are endowed with the property of being able to grow up to resemble the body from which they were split off. Thus growth is enabled to take place continuously. The tissues of the parent individual become highly specialized for their various tasks, and in this specialization they lose their potential immortality. The parent, sacrificing its power of continuous growth to its offspring, courts death in the specialization of its own tissues.

We have now traced what advantages accrue to organisms from the power of reproduction. But in our study of the evolution of reproduction we have not as yet mentioned

sexual reproduction. In what precisely does sexual reproduction consist ?

SEXUAL REPRODUCTION

The essence of sexual reproduction is that two small pieces of living matter, split off generally from two adult bodies, *fuse together* into one piece of living matter which grows to resemble its parents. We do not know how this process originated, but it seems logical to conclude that the earliest animals had no sexual reproduction. At the present day there are many animals whose germ-cells may become split off from the parent body, and grow up to resemble that parent without fusing with another such piece. For instance, the plant-lice which often abound on roses reproduce largely by this means. During the summer they lay eggs which are never fertilized, but each of which none the less grows up into a new individual like its parent. But this process does not continue indefinitely ; sooner or later eggs are laid which require fertilization.

The division of the individuals of a species into two categories, male and female, is not a necessary concomitant of sexual reproduction, for two quite similar organisms might well produce two similar gametes (reproductive cells), which, fusing together, would give rise to a new individual. But a much more efficient method of securing the same end is nearly always adopted. This is the specialization of the gametes into two sorts, sperms and eggs (see Fig. 2). The sperm and the egg have this in common, that each carries the innerited qualities of the

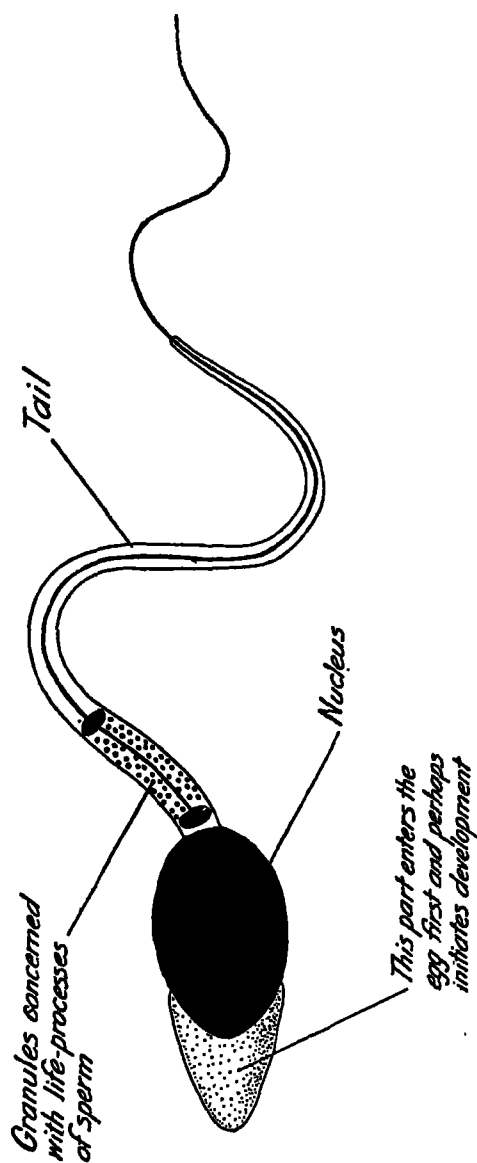


FIG. 3.—A SPERM, HIGHLY MAGNIFIED (DIAGRAMMATIC).

body from which it arose ; but in every other way they are amazingly different.

The differences between sperm and egg are to be accounted for merely on the principle of division of labour. Just as it is profitable in a community of people that some should follow one trade and excel at it and some another, rather than that all should perform all trades badly, so also in the reproductive elements of the living organism it is advantageous for one type of gamete to be specialized for finding the other, and the other modified by the inclusion of sufficient reserve food-material to start the new individual in development before it has had time to acquire a mouth and digestive system for itself. Of course, each gamete might be locomotory and at the same time might carry reserve food-material ; but quite obviously locomotion would be seriously impeded by the reserve food, or if the amount of food were sufficiently small to allow easy locomotion, then it would be insufficient to meet the demands of the embryo.

Reference to Fig. 2 will serve to show the differences between sperms and eggs. The figures are drawn to the same scale. The sperm (better seen at higher magnification in Fig. 3) consists of practically nothing except the nucleus, which is concerned in the transmission of the parental characteristics, and the tail which lashes violently from side to side and is the organ of locomotion. The egg, like the sperm, is provided with a nucleus for purposes of inheritance, but in all other respects it is entirely different. It is often one hundred thousand times as large as the sperm ; it is quite unable to move ; and it is loaded with reserve food-materials in the form of "yolk." Eggs vary con-

siderably in size. . Often they are quite invisible to the naked eye ; often, as in the case of mankind, they are just visible ; sometimes, as in the case of birds, they are so stuffed with food materials as to be relatively enormous.*

Granted that it is of advantage that there should be two types of gamete, it is not hard to understand that it is easier that one type should be elaborated by one individual, and the other type by another individual. This is the first sign of differentiation into two sexes. The individual which produces sperms is the male ; that which produces eggs is the female.

In many primitive animals, the only difference between the male and female is that one produces sperms and the other eggs. They are indistinguishable unless one dissects out the reproductive organs and examines them. This is the state of affairs, for instance, in the sea-urchin. Here some individuals elaborate sperms, others elaborate eggs. When the sperms and eggs are ripe, they are shed into the sea. The eggs float about at the mercy of wave and current while the sperms swim by movements of their tails until they chance to come into contact with the eggs.

Now this obviously involves an enormous waste of sperms and eggs. The chances of any given egg being fertilized are exceedingly remote. Further, this method of achieving fertilization is not applicable to terrestrial animals, for sperms have no means of travelling over dry surfaces. Accordingly, in the higher marine animals and in all terrestrial ones, the male individual seeks out a female individual and either deposits its sperms over the

* The true egg of the bird is what is commonly called the yolk. The white and shell are secreted round it after it has left the ovary.

eggs as soon as the latter have been laid by the female, or by copulation inserts them directly into the latter's body, to fertilize the eggs within it.

Thus, in general, the male parent in seeking out its mate copies the activities of its sperms, while the female shows the same passive nature as its eggs.

It should be noticed that there is no rigid reason why it should be the individual which produces sperms that seeks out its mate, and why the individual which produces eggs should be relatively passive, and this state of things is, indeed, not invariably the case. In the grebes, for instance, both sexes are equally active in mating matters, while in the phalaropes it is the female that seeks the male. These, however, are but exceptions to prove the general rule.

We have now discussed two of the problems which confront us, and have come to some reasonably satisfactory conclusions about them. We have discussed the origin of reproduction and found several reasons why continued growth without reproduction is impossible ; and we have found why sexual differentiation of the germ-cells and then of the parent individuals themselves has followed on the heels of sexual reproduction. But we have not discussed the significance of sexual reproduction itself ; we have not found out how it is to the advantage of the species that two gametes should fuse together to form an individual.

Rather than discuss what must always be hypothetical in the extreme, namely the origin of sexuality, we will try to ascertain what benefits are derived from it when once it has evolved.

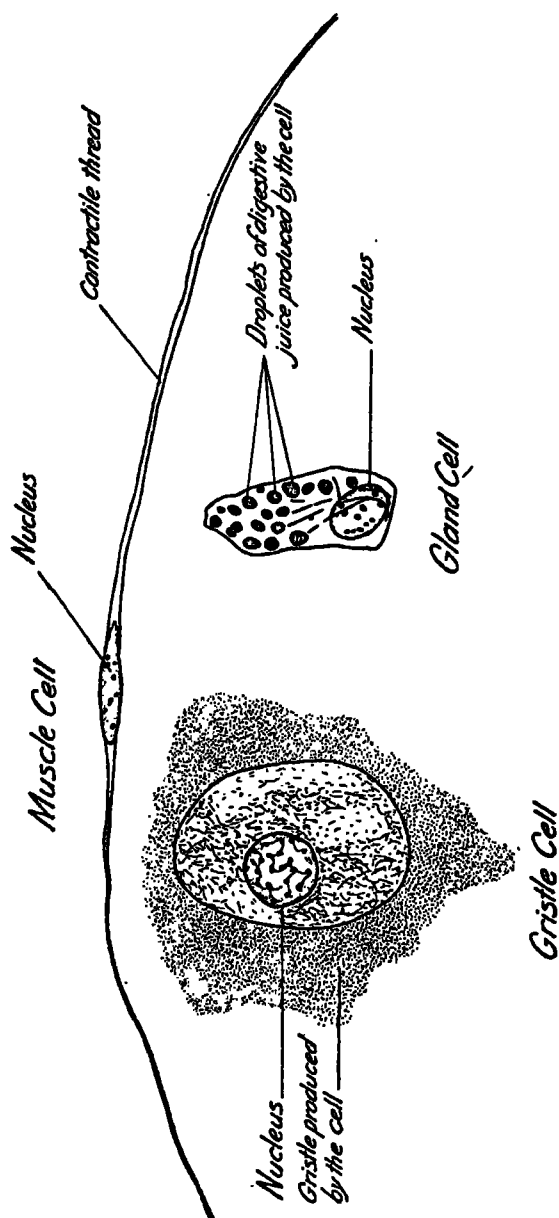


FIG 4.—A MUSCLE CELL FROM THE BLADDER OF A CAT; A GRISTLE CELL FROM THE RIB OF A RABBIT; AND A GLAND CELL FROM THE PANCREAS OF A FROG. HIGHLY MAGNIFIED. (THE MUSCLE CELL IS SOMEWHAT LESS HIGHLY MAGNIFIED THAN THE OTHER TWO.)

In order to understand this properly a rough outline of certain fundamental points in the minute anatomy of organisms is required.

THE CELL

Animals and plants consist of minute masses of living material which, to use a well-worn simile, are to the living organism what bricks are to a house. But the analogy would only be complete if every object in the house were formed of, or by, bricks. To these little masses of living material the name "cells" was unfortunately applied by their early observers under a mistaken conception of their nature; and this misnomer has stuck to them with such obstinacy that it is impossible to free them from it. The objection to the word "cell" is its implication of emptiness.

Nearly all "cells" are so small as to be quite invisible to the naked eye. When viewed under the microscope they are seen to vary very considerably in their shape in accordance with what functions they have to perform. For instance, a muscle-cell is elongated and contractile (Fig. 4); a gland-cell is compact and contains globules of the material it secretes; a gristle (cartilage) cell is oval and surrounded by the gristle which it produces. A living animal or plant consists wholly of cells and of the products of cells, and of nothing else. The sperms and eggs are themselves cells.

Enormously varied as the different cells that compose the body are, they all have one point in common; every cell

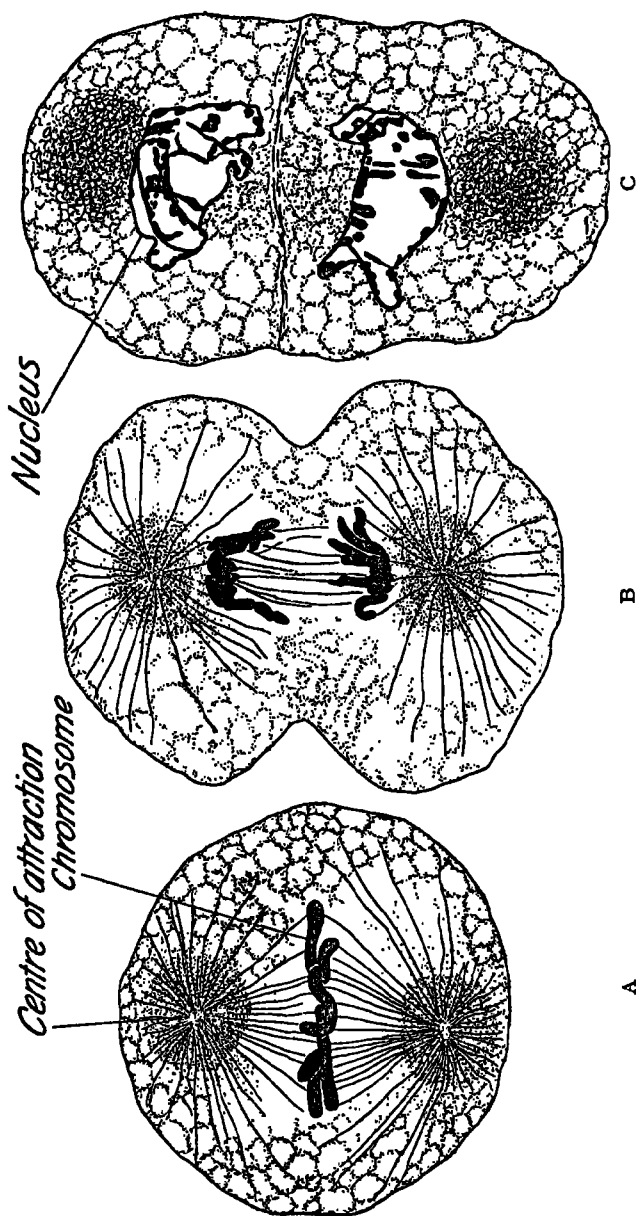


FIG. 5.—CELL DIVISION (THE EGG OF A THREADWORM DIVIDING INTO TWO CELLS). HIGHLY MAGNIFIED.
 A.—The nucleus has resolved itself into four chromosomes, which are seen lying between two radiating centres of attraction.
 B.—Each chromosome has split longitudinally into two equal parts of which one has travelled towards one centre of attraction and the other towards the other. The four chromosomes at each pole are beginning to fuse together to form a new nucleus. A constriction is beginning to divide the cell into two.
 C.—The two groups have formed nuclei. The constriction has completely divided the cell into two. The two cells are closely pressed together.

is found to have within it a nucleus corresponding to the nucleus of the sperm and of the egg, which we have already mentioned and figured.

When the sperm meets the egg they undergo complete fusion, and their nuclei become fused together to form one nucleus. Thus every organism starts life as a single cell. This cell divides into two, and these two each into two, making four, the four into eight, the eight into sixteen, and so on. In this way the number of cells grows rapidly, and every single cell in the body is formed by division of a pre-existing cell.

When a cell divides its nucleus divides also, one half going to each of the two cells formed. Thus every nucleus is derived from the nucleus of the fertilized egg—that is, it is derived from the fused nuclei of the sperm and of the egg.

We have already mentioned that it is the nucleus that hands on the factors for the parental characteristics to the offspring; and thus it comes about that every cell in the body contains within it the heritage of the father and of the mother.

Now we come to a most critical point. When a cell is about to divide, its nucleus becomes resolved into a number of small rods, which have been called “chromosomes,” on account of the fact that they are extremely deeply coloured by certain stains (Fig. 5). At cell-division each chromosome divides into two, and one half of each chromosome goes into each of the two cells formed.

The chromosomes in a single cell vary considerably in length, and it is always the case that there is a pair of chromosomes of each length. Suppose we find in a cell two very long chromosomes, two rather long ones, two of

medium length, two short ones, and two very short indeed ; then in every cell of the body (the gametes excluded) of every individual of that species* the same set of chromosomes will be found—two very long, two rather long, two medium, two short, two very short.

In man the number of chromosomes is 48 ; in most insects it is between eight and eighteen ; in a species of threadworm which inhabits the intestine of the horse the number is two.

Now we have had to exclude the gametes from our generalization about chromosome numbers. The gametes have only half the number of chromosomes characteristic of all the other cells of the body. The reason will be evident upon a moment's reflection. Suppose the sperm of man carried 48 chromosomes in its nucleus, and the egg carried the same number ; then the child resulting from their union would necessarily have 84, double the normal number of chromosomes, and the number of chromosomes would be redoubled with each generation.

This state of affairs is avoided by the following arrangement. The cells that will give rise to gametes divide normally at first till there is a large number of them. At each division each chromosome divides into two just as in every other cell in the body. But then a peculiar division occurs called the "reducing division" ; the chromosomes do not each divide into two. On the contrary, one member of each pair of chromosomes goes into one of the two cells formed by division, one into the other. The result is that each cell comes to contain *half* the normal number of

* This statement is not quite exact. The nature of its inexactitude will be explained in the next chapter.

chromosomes—a set of only *one* of each length instead of the normal *two* of each length.

Since the sperm and the egg each contain half the full number of chromosomes, the full number is restored when they fuse together at fertilization. It follows that of the two chromosomes of a certain length in any cell in the body, one was derived from the sperm, that is from the father, and one from the egg, that is from the mother.

Now the reader may well wonder why such great stress has been laid on the chromosomes. The reason is that it is by the chromosomes that the factors for the inherited qualities are passed on from parent to offspring. By a minute analysis of breeding results with a species of fruit-fly, the American biologist, Morgan, and his collaborators have been able to say with almost complete certainty that certain characteristics are inherited through the agency of the longest pair of chromosomes, certain other characteristics through the second longest pair, others again through the next pair, and a few through the very short pair of chromosomes. Whatever it is in the chromosome that determines a given character is called the "factor" for that character.

Now at last, after this rapid survey of the chromosome theory of heredity, we come to the point. What is the advantage of sexual reproduction?

THE ADVANTAGES OF SEXUAL OVER ASEQUAL REPRODUCTION

Imagine an animal reproducing *without* sexual reproduction. Let us take, for instance, the plant-lice mentioned

before. Here no peculiar "reducing" division occurs in the ripening of the germ-cells, and no chromosomes are brought in from another individual. So all the eggs grow up with precisely the same chromosomes as their parent. They therefore grow up precisely *like* their parent except for any modifications that may be caused by the environment, such as drought, extremes of temperature, nature and abundance of food, etc. Now modifications caused by the environment are not inherited. The result is that evolution cannot take place. No new varieties can appear except by the very rare process called "mutation."

Compare this with *sexual* reproduction in a species which has ten chromosomes.

Every cell in the body of a female individual of this species contains five pairs of chromosomes, and of each pair one comes from her father and one from her mother. The probability is that of each pair of chromosomes the one derived from her father differs from the one derived from her mother. When the cells that will give rise to the eggs go through the peculiar division, mentioned before, in which the chromosomes, instead of dividing, become sorted out into two groups, there will be a number of possibilities as to the chromosome constitution of the resulting eggs.

Let us give the ten chromosomes letters to distinguish them. Let us call them A, a, B, b, C, c, D, d, E and e. A and a are a pair; so are B and b, and so on. In each case the capital letter (*e.g.*, A) stands for a chromosome derived from the female's father, and the small letter (*e.g.*, a) for one derived from her mother.

At the "reducing" division, A goes to one cell, a to

the other; *B* goes to one cell, *b* to the other ; and so on. *But A may go to the same cell as B, or it may go to the same cell as b.* Thus we get the following 32* possible types of egg :

| | | | |
|-------|-------|-------|-------|
| ABCDE | AbCDE | aBCDE | abCDE |
| ABCDe | AbCDe | aBCDe | abCDe |
| ABCdE | AbCdE | aBCdE | abCdE |
| ABCde | AbCde | aBCde | abCde |
| ABcDE | AbcDE | aBcDE | abcDE |
| ABcDe | AbcDe | aBcDe | abcDe |
| ABcdE | AbcdE | aBcdE | abcdE |
| ABcde | Abcde | aBcde | abcde |

Consider now a male of the same species. It is evident that he produces 32 different types of sperm, and probably the 32 all differ in their heritages from the 32 eggs. Chance mating of each type of sperm with each type of egg gives a possibility of no fewer than 1,024 different types of individual. Small wonder that no two children born of the same parents (identical twins excluded†) are precisely alike !

Out of this multitude of different types of individual there are considerable chances that some will be better fitted for existence than others ; and in this rigorous world where survival of the fittest reigns these will be the ones that will, as a rule, survive. The conclusion we have

* There are many more than 32 possible types of egg, if what is known as "crossing-over" is taken into account.

† Identical twins are alike because they arise from the division of a single fertilized egg into two separate parts. Since they arise from the same fertilized egg, they carry precisely the same chromosomes. Often twins arise from different eggs fertilized by different sperms. Twins of this sort are no more alike than ordinary brothers and sisters.

reached is that sexual reproduction gives enormous possibilities for improvements in the race, by making possible innumerable new combinations of characters.

It is well known that the eggs of most animals will not develop unless they are fertilized. This has given rise to the idea that there is some life-giving property in the act of fertilization, and that the object of sexual reproduction is to obtain the advantages of this property.

This idea is probably incorrect. The advantage of sexual reproduction is that it gives scope for the combination of different characters : and to enable this advantage to be obtained it is necessary that the egg should not develop until it is fertilized. Accordingly, in the course of evolution, the egg has acquired the property that it will not develop unless it is fertilized.

A metaphor will make the matter clearer. Let the reader imagine two people, one an imbecile and one a normal person. The imbecile wishes to travel abroad, but in his guardian's opinion his foreign travel would be more advantageous to him if a friend accompanied him. Accordingly, his steamship ticket is taken from him and given to his friend, so that he cannot travel unless his friend travels with him. *But the giving back of the ticket by the friend to the imbecile, when they meet to go abroad together, is no explanation of the advantages of foreign travel, nor does it explain how the steamship was invented.*

If we read " unfertilized egg " for " imbecile," " sperm " for " friend," and " development " for " foreign travel," the meaning of the metaphor becomes clear. The giving back of the ticket is the giving back by the sperm of the power to develop, which the guardian, natural

selection,* had taken away; *but this giving back gives no explanation of the advantages of sexual reproduction, nor does it explain how the power to develop was originally gained.*

No doubt the power to develop without fertilization was the earliest condition. Then, sexual reproduction having evolved, the ability to develop without fertilization was taken away by natural selection, so that the advantages of sexual reproduction could not be escaped.

The power to develop after fertilization is not some new property, the result of sexual reproduction. It is the old original power to develop, now only possible after fertilization.

In order that all the rather abstract ideas which we have so far discussed may be brought into line with known facts, let us turn our attention to the sexual phenomena of the single-celled animals.

Before we can appreciate the meaning of these phenomena, it is important to understand something of the process whereby many-celled animals evolved from single-celled animals.

Now single-celled animals reproduce by simple division into two. It seems very probable that long before there were any many-celled animals in the usual sense of the term, some single-celled animals changed their mode of life in that the two daughter-cells formed by division did not separate completely, but remained together. This habit was further perfected until many divisions passed without separation into component cells, so that quite a

* The principle of evolution by natural selection of the best adapted variations is briefly touched on in the next chapter.

large colony was formed. At the present day there are colonies of single-celled organisms of this sort. Each cell derives benefit from its closeness to the other cells and yet it is not so dependent on the other cells that it could not live without them. It is difficult to say whether this group of cells is to be regarded as a colony of single-celled animals, or as a single many-celled animal. It is probable that many-celled animals evolved in this way from single-celled ancestors.*

In the most specialized of these colonies of single-celled animals, certain cells are set aside as germ-cells. In the less specialized ones, all the cells have the power of becoming germ-cells, and occasionally the whole colony breaks up into a number of gametes, each of which fuses with another, generally from another colony, and the process of colony-formation by division without separation starts again. The fusion of these cells corresponds with the fusion of sperms with eggs in the higher animals. In some cases the two cells which fuse are rather different from one another ; in other cases they are similar.

In those single-celled animals where no colony-formation takes place, in which the cells separate completely from one another after division and live separate lives, simple cell-division does not continue indefinitely. In the end cells fuse together in pairs.

Evidently all the cells arising by simple division from a single cell formed by fusion of two cells, correspond to all the cells of a single individual of one of the many-celled

* I am well aware that some biologists do not derive many-celled animals from colonies of single-celled animals, but nevertheless I think that this is the most likely explanation of their evolution.

animals. But whereas in a single individual in the many-celled animals all the cells work together for the general good of the whole individual, in these separate single-celled animals no cell is of any benefit to any other cell, and we cannot possibly call all the cells produced by division an "individual," although they correspond to an individual in the many-celled animal.

Now let us take a single case and follow it out carefully, to see whether we can find anything to throw light on the meaning of sexual reproduction. We will choose the little Paramecium (Fig. 6), which occurs so abundantly in stagnant water. It is oval and about one-hundredth of an inch in length, and it is clothed with little hair-like structures which beat rapidly in one direction and more slowly in the other, and thus propel the whole animal.

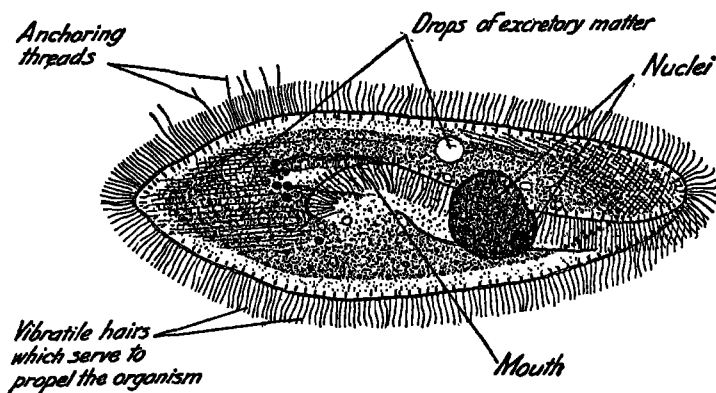


FIG. 6.—PARAMECIUM, HIGHLY MAGNIFIED. THE NUCLEAR MATERIAL OF PARAMECIUM IS CONTAINED IN TWO SEPARATE BODIES, ONE MUCH LARGER THAN THE OTHER. THE SMALLER ONE ONLY IS CONCERNED IN CONJUGATION, THE LARGER ONE DISAPPEARING ALTOGETHER DURING THIS PROCESS.

Paramecium multiplies by simple transverse division

into two. The two individuals produced by division separate and swim away, and have nothing further to do with one another. Occasionally, however, they conjugate in pairs;* that is, sexual reproduction sets in (Fig. 7).

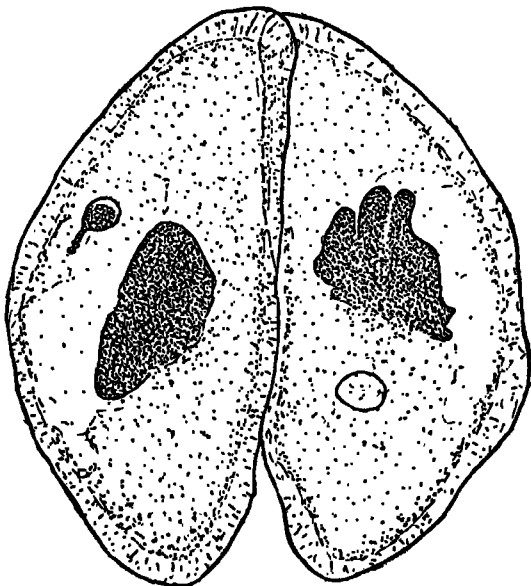


FIG. 7.—TWO PARAMECIA CONJUGATING. (Drawn from a preparation made by Prof. E. S. Goodrich.)

In order to find out what benefits are derived from sexual reproduction, *Paramecia* were kept under constant observation for a number of years. Each *Paramecium* was kept in a separate watch-glass, and when it divided into two, one of those two was removed to another watch-glass. In this way conjugation in pairs was prevented. Sexual reproduction could not take place. Under these circumstances

* The process is rather different from fusion.

the rate of division gradually decreased, and in the end the animals usually died. Their death could generally be prevented and rapid division restored by changing their diet. Death was also prevented in the case of some individuals if conjugation were allowed to take place, though the rate of division was not increased at once; in the case of other individuals death followed conjugation.

These results are explained on the assumption already made that the advantage of sexual reproduction is that it enables innumerable different combinations of characters to take place. In the case of *Paramecium*, those individuals which were saved from death by conjugation were those which made fortunate combinations, adapted to the unfavourable conditions which were gradually destroying the race when sexual reproduction was prevented. But many conjugating individuals did not benefit from conjugation; these individuals were those which happened to make unfavourable combinations.

The case of *Paramecium* when properly analysed shows clearly that there is no mysterious benefit in conjugation as such, for if this were so, all individuals should benefit from it, whereas actually only a few benefit.

If in any pool of water the conditions gradually change from time to time, sexual reproduction alone makes continued existence possible for *Paramecium*. When the conditions begin to get too bad, conjugation takes place, and innumerable new varieties of *Paramecium* are formed, some adapted to the new environment, others not adapted to it. The adapted ones will, of course, survive and multiply until the conditions become unfavourable, when a

recombination of characters again preserves the race from extinction.

There is another advantage in sexual reproduction which must be pointed out before the chapter is brought to a close.

Evolution has not consisted simply in the recombination of *old* factors. From time to time a "mutation" takes place. A mutation is a sudden change from the normal type which appears in an individual and which is inherited. The causes of mutation are not understood. A mutation may be large—a new breed of sheep has arisen by a single mutation; or it may be minute, as in the case of the mutation which affects two hairs only visible under a magnifying glass on the side of the body of the fruit-fly.

Now if there were no such thing as sexual reproduction, it is obvious that a new mutation could not be brought into combination with other factors than those already existing in the individual in which the mutation appeared. But with sexual reproduction the new mutation is quickly brought into combination with all sorts of already existing combinations, and if it is advantageous in combination with any of them, the species benefits.

CONCLUSION

Sexual reproduction increases the variability of the species by causing the combination of existing factors in a multitude of different ways and by bringing new mutations quickly into relation with a large number of already existing

combinations. Evolution results from the natural selection of such of these combinations as are beneficial.

Eggs possess the power to divide rapidly after fertilization to give rise to new individuals. It is important that the egg should be kept from dividing until fertilized, for otherwise fertilization would often not take place and the advantages of sexual reproduction would be lost. But sexual reproduction has no mysterious, rejuvenating, life-giving influence at all.

CHAPTER II

SEX CHARACTERS

INTRODUCTION

IT has been customary for zoologists to designate the various characters which distinguish the sexes as primary sexual characters, accessory sexual characters, and secondary sexual characters. The primary sexual characters are the "gonads," that is, the testes and ovaries. The accessory sexual characters are the obviously useful sex characters other than the testes and ovaries, such as the vas deferens, down which the sperms travel in the male, and the vagina which receives them in the female. The secondary sexual characters are those which seem not to be directly concerned in reproduction, such as beards, antlers, and crests, and all the wonderful colours and plumes which characterize the males of so many animals. I may anticipate what follows by saying that the distinction between accessory and secondary sexual characters is not so clear-cut as was formerly supposed.

In this chapter I depart from the method I have adopted in the rest of the book, in that I introduce the subject from the historical standpoint by reviewing first some of the earlier ideas on the problems involved. I do this because they have been treated at considerable length by the greatest biologist of all time, Charles Darwin. When

I further remark that Darwin's treatment of the subject was adversely criticized by Alfred Russel Wallace, the co-founder of the natural selection theory of evolution, it becomes evident that a mere recitation of the modern view would be insufficient.

In order to understand the problem with which we have to deal, it is necessary to be clear on Darwin's theory of natural selection.

Darwin's theory bases itself firstly upon the variations which occur so abundantly in nature, and secondly on the probability that those individuals which have favourable variations will tend to survive in the struggle for existence more often than those individuals which are not so fortunate. The struggle for existence is caused by the production of far more individuals than could possibly survive.

It is evident that the evolution of any character can be accounted for on this theory if that character is of advantage to the species in the struggle for existence and provided that favourable variations occur. Thus we may account not only for all the various organs of digestion, respiration, etc., but also for the accessory organs of reproduction, such as the vas deferens, the bags which store the sperms, the glands which add a useful secretion to the semen, and the copulatory organs. It is obvious that those individuals which have efficient means of carrying the sperms from the testes, of storing them, of preserving them in a functional state, and of stimulating the female to active participation in sexual congress by appropriate copulatory organs, will tend to leave more offspring than those individuals in which these functions are less satisfactorily carried out.

The offspring will inherit the parents' advantages. The evolution of the accessory sexual characters can thus be explained on the theory of the natural selection of the fittest.

But it is often difficult to see how natural selection could have resulted in the evolution of the secondary sexual characters. Of what value is the beard of man, or the brilliant plumage of a male paradise-bird (Fig. 8) in the struggle for existence?—and if they are of no use, how have they evolved?

THE THEORY OF SEXUAL SELECTION

Darwin's theory to account for these apparently useless organs is his famous theory of sexual selection. This theory is that the female tends to choose for her mate that male which stimulates her sexual emotion to the highest degree. The males of a species vary in their appearance, and Darwin's theory is that it is, on the whole, those males which have the most striking or beautiful appearance, or which behave in the most remarkable or attractive manner, that are accepted by the females. These males hand on their peculiarities to their offspring. Darwin thought that the evolution of secondary sexual characters could not come under the head of ordinary natural selection, *because he considered their evolution to be of no value to the species*.^{*} He therefore coined the term "sexual selection."

^{*} There is some doubt whether Darwin himself believed these characters to be so completely useless as is usually assumed from his writings.

The theory of sexual selection was attacked by Wallace, on the ground that there is no evidence except in a few cases that the female exerts any choice. Further, except in species where a number of females associate with one male, choice by the females would make no difference to the next generation ; for even if the more attractive males were generally mated first, the less attractive ones would be mated sooner or later if the number of males were the same as the number of females.* Wallace further pointed out that the call-notes and marks of sex-recognition could be accounted for on the principles of ordinary natural selection, as being of obvious use to the species in enabling the sexes to find one another.†

Wallace agreed with Darwin, however, that many sexual ornaments, as well as curious antics and displays by the male sex, were useless to the species. But his theory to account for these supposedly useless organs was quite different from Darwin's. He attributed the displays of the male sex to the same cause as the play of many young animals—namely, superabundant energy. He went still further and attributed also to superabundant energy the bright colours and long plumes and ornaments of the male. He pointed out that these colours and ornaments are developed in regions where muscular and nervous tissue are most developed.

Wallace supposed that the female sex was prevented

* To this it was replied that the offspring of the more attractive males would be the most likely to survive, because they were born earlier in the year, and were therefore older and better able to stand the rigours of winter or of migration.

† It has been made probable that the song of the male is as much a warning to other males to keep clear of already occupied territory as an invitation to the female.

from taking on these bright colours because of the danger of their attracting the attention of enemies during the incubation of the eggs. Natural selection would wipe out brightly-coloured females, except in species in which the nest was so constructed or so placed that a brightly-coloured female could not be seen when sitting. In the latter case it would not be necessary for the female to be dull-coloured; and indeed the females of the kingfishers, woodpeckers, parrots, etc., whose nests fulfil these conditions, are as brightly-coloured as the males.

Wallace pointed out that on his theory it would be the most vigorous males that would have the brightest colours and best ornaments, and since natural selection would preserve the most vigorous males, it would also tend to preserve the most brightly-coloured, although the bright colours might be actually disadvantageous. Further, he pointed out that in polygamous species the most vigorous, and hence the most brightly-coloured males, would secure the greatest number of females and therefore have the greatest number of offspring, *not* because they were brightly coloured but simply because they were vigorous.

But although we may agree with Wallace that natural selection has probably kept dull the females of species which build open, exposed nests, it is difficult to believe in his theory that superabundant activity or excess of musculature or nerves could be the cause of the production of beautiful crests and plumes of bright colours. If the bright colours were due to the deposition of pigment, it is just conceivable that increased activity or "rate of life" might result in increased deposition of pigment, and, therefore, darker (but *not* brighter) colours; but in a very

large number of cases the colours are not due to pigment at all, for it is the *structure* of the surface that produces the colour by breaking up the light falling upon it into its coloured constituents and reflecting them.

Now let us turn to modern lines of thought, though we shall have to turn back again to Darwin for the correct elucidation of the way in which certain "secondary sexual characters" evolved.

THE USE OF APPARENTLY USELESS SEX CHARACTERS

The important point to realize at the outset is that it would not be to the advantage of animals to be anxious to mate at all times during the breeding season. If this were the case, not only would much time be wasted and many sperms lost on already impregnated females, but it might be a positive danger for animals to devote so much time to anything which renders them so oblivious to their surroundings and, therefore, such a prey to enemies.

It has, therefore, come about in the higher animals that one sex (the female) is only willing to receive the male at intervals—sometimes (mammals) at quite definite intervals, sometimes (birds) at less definite intervals. It has often come about also that the female requires a certain stimulus even when she is in a "willing" state. This stimulus is afforded by the display of the bright colouration and ornaments of the male, which are in many cases only exhibited when he is in a state of great sexual excitement. For instance, bright feathers and parts of feathers are often so disposed that they are only visible when he raises

his crest or extends his wing, under the stimulus of the presence of a "willing" female. The advantageous result ensues that sexual congress only takes place when both sexes are ready to play their appropriate parts in it effectively; and there is less danger and no waste of time nor of sperms such as would necessarily result if both sexes were "willing" at all times during the breeding season.

Granting this, we see at once that the brightly-coloured ornaments of the male, and the various antics which he performs under the influence of sexual excitement, *are not useless at all*, but highly beneficial to the species; and as such they are preserved and improved by the action of natural selection.

We may understand this point more clearly by comparing the action of the male copulatory organ with that of the male ornaments. The copulatory organ of mammals has, of course, the effect of stimulating the female and thus causing the rhythmic contractions of the vagina and uterus, which result in sperms being ejaculated by the male and sucked up into the uterus by the female. The male copulatory organ has been developed and perfected by natural selection, since males possessing copulatory organs which were effective in stimulating the female, would tend to have more offspring, similarly provided, than those in which the copulatory organs were less efficiently developed. It is not that the female chooses a certain male for her mate because his copulatory organ is effective, but *because the copulatory organ is effective, efficient impregnation results*. Choice by the female is not concerned.

Just as the male copulatory organ is of great importance

in stimulating the female in the later stages of the mating process, so the bright colours, the ornaments, and the display of the male are useful in earlier stages before union has been effected. It is not that the female chooses the brightest male from a number of males, but that where two animals are concerned, a male and a female, the likelihood of effective impregnation taking place is greatest if the male has bright colours and shows them to advantage. The bright colours are equivalent to the copulatory organ ; both are accessory sexual characters, and both have been evolved by *natural, not sexual, selection*.

First acquaintance with this thesis is often confusing, and I will give a few examples to make the distinction clear.

In non-migrating song-birds, such as buntings, the birds pair off, one male with one female, in early spring. No ceremony, no display of any kind takes place before the pairing off, so that there is no question of the female choosing the male which displays best. *It is after the pairing-off has taken place that periodical display begins.*

The newt furnishes another case in point. In the breeding season the male acquires bright colours along his sides, and a large crest grows out along his back. Finding a female, he deposits near her a bundle of sperms, held together by some sticky substance. He then devotes himself to swimming about actively and displaying his charms before the female. If the latter is sufficiently aroused by his antics, she swims to the bundle of sperms, picks it up and forces it into her egg-tube so that fertilization may be effected. The male's desires are satisfied by the sight of her performance of this process.

If we apply the theory of sexual selection here, we must

consider that the bright colours of the male evolved by the female tending always to choose the sperm-bundle of the brightest and most active male. But if a number of males were to surround a single female, each ready to discharge his bundle of sperms, when, in fact, there might appear to be some possibility of "choice"—then the theory of sexual selection would be refuted. Each male would deposit his bundle and go off into the characteristic ecstasy. But there is no evidence that the female could choose the bundle belonging to the brightest male or the best performer. On the contrary, she would select any bundle at random, for it would be extremely unlikely that she could discover and remember which bundle belonged to which male. It is necessary that the male should be brightly-coloured and should display so that the female may be sufficiently excited to pick up a bundle of sperms; but she would not—could not—pick up the bundle belonging to the brightest male rather than that of the dullest.

It is to be remembered that if one male alone is concerned, and if its colours and antics are not sufficiently attractive, then its bundle is not picked up and it does not become the father of offspring, and so its dulness is not perpetuated; but if a dull male competes with several brightly-coloured males, then the female is sufficiently excited by the others to pick up a bundle, and that bundle is as likely to be that of the dull male as that of any of the others. *In newts, then, whenever there is a semblance of competition between males for one female, then there is absolutely no question of choice by that female.*

It is interesting to note that in those species of newt in which the male clasps the female, no bright colours are

developed. If we interpret the clasping instinct and the strengthened and modified arm as accessory sexual characters, it is hard to deny the same interpretation to the bright colours of those males which do not clasp.

An experiment with the fruit-fly may be given as a last instance. The courtship consists in the stretching out of the wings alternately by the male. After quite a short time copulation takes place. If the wings are cut off from a male, the process takes much longer. Evidently the male with wings stimulates the female more effectively than the wingless male. But now let us examine what happens if a winged and a wingless male are allowed to compete for a single female. The female chooses the wingless male about as often as she chooses the winged, and she copulates with him after the lapse of time characteristic of courtship with a normal male. When she has the opportunity to choose she does not do so. She is stimulated chiefly by the winged male, and when sufficiently stimulated she is prepared to copulate, but with whom she copulates is a matter of chance.

SEXUAL SELECTION IN POLYGAMOUS BIRDS

Although, as these examples have shown, sexual selection has not been responsible for the majority of ornaments and displays, yet there are cases in which it has probably played a part. Many polygamous birds assemble early in the mating season, and the males display their charms before the females. The ruff is a good example. The male differs from the female in the possession of a large

erectile ruff. At times of assembly, the males enact a veritable fashion parade, displaying their ruffs to the best advantage before the females. It is probable that the most attractive males get the most mates and therefore transmit their attractions to the greatest number of offspring. The least attractive males get no mates and leave no offspring. The males are very variable in colouration, and this variety gives an opportunity for the females to exert their choice in the matter of the markings as well as the size of the ruff.

It is carefully to be noted that whether natural selection or sexual selection is at work, beauty comes via the æsthetic sense of the opposite sex. In the minds of many naturalists this is an insuperable difficulty in the way of accepting these theories, for the evolution of the æsthetic sense has itself to be accounted for. But this is probably not a valid argument. Just as it is to the advantage of the species that the male is able to advertise his readiness to copulate, so it is to the advantage of the species that the female should be able to read his advertisement. The development of the female's æsthetic sense is thus accounted for ; and there is no reason why the male should ever attain the state of excellence which completely satisfies that æsthetic sense.

BEAUTY IN MANKIND

In mankind matters are enormously complicated by the development of the mind. It is probable that both natural and sexual selection have played their parts in

the evolution of the apparently useless sex differences. That sexual selection has played a part is indicated by the fact that on the average it is the handsomest people that tend to get married in primitive races as in civilized communities.

It is curious that the beard, which is usually considered to have evolved as a stimulus to the female sex, is now often regarded as the reverse of an attraction.* Perhaps there is an alternative explanation of its evolution. It may be that it evolved as a check to homosexual tendencies, which, if at all common and if unchecked, would have a devastating effect on the birth-rate. If this is true, then natural selection has evolved a beard in the male and at the same time, also in the male, a sexual repugnance to a beard. This repugnance of one sex, as far as sexual congress is concerned, results in appreciation of the other sex. If this seems an unlikely hypothesis, it should be remembered that homosexual tendencies are common in animals, in primitive races, and unfortunately also in civilization, and that they therefore were probably common in our ancestors.

SEXUAL SELECTION BY COMBAT

So far we have discussed only the evolution of organs and habits adapted to entice the other sex to sexual con-

* Of course we must attach little importance to the modern dislike of beards, for people tend to a very great extent to consider whatever they have been used to as right and proper. It is uncertain why men first started to shave the chin; but when the fashion had become widespread, those who were growing up found nearly everyone without a beard and *therefore* grew up with the idea that a beard was unattractive.

gress. But there are other organs and instincts than these which we have yet to discuss, whose evolution was also attributed by Darwin to a form of sexual selection. I refer to the fighting weapons of many male animals, such as the antlers of deer and the spurs of cocks. Darwin pointed out that species which have these weapons in the male sex only are generally polygamous. The sex ratio being approximately one male to one female, competition arises between the males ; and competition takes the form of battle. In these battles one male often kills the other, and in any case the best-equipped and strongest males have the largest harems and so produce the most offspring. The evolution of antlers and spurs has probably been brought about partly in this way, as well as the evolution of protective devices, such as manes. It is carefully to be noted that in so far as they have evolved in this way they are quite useless to the species.

But another factor may have influenced their evolution. Stags often fight strenuously with their antlers to protect their harem of females and their offspring from the attacks of carnivorous animals, and so it is probable that antlers have been produced partly, at least, by natural selection.

Darwin thought that yet a third factor might be involved, namely, the selection by the females of the males with the largest and most attractive-looking antlers. The truth of this is doubtful, though it would admittedly appear that antlers would be more efficient as fighting weapons if they were less extensively branched.

It follows from what has gone before that there are two sorts of sexual selection, namely, selection by the female, and selection by combat. We have seen that the first type

of sexual selection rarely takes place except in polygamous birds and in mankind, whereas the second type may have been an important factor in the evolution of the weapons and great strength of the males of many species. We may next enquire whether this latter type of sexual selection is the cause of the greater stature and strength of the male among mankind.

At first sight it might seem probable that such is the case, and there would be good reason to suppose so if man's pre-human forefathers were polygamous, and therefore fought with rivals for their brides. But from the analogy of the higher apes, in which the male associates with but one female, we must conclude that sexual selection has not been an important factor. We know that the male of the higher apes associates with the female during the growth of their offspring, and that he protects both; and thus it is evident that his greater size and strength can be attributed to natural selection. It is reasonable to suppose that the same applies to the ancestors of man.

SEX CHARACTERS CONCERNED WITH THE CARE OF OFFSPRING

This introduces us to the type of sexual difference which is quite uncorrelated with the effective performance of sexual congress, and which should be classified with the womb and breasts of the female as sex characters concerned with the care of offspring. With these must be associated all the instincts of maternal care, which play such a large part in the behaviour of the higher animals. These instincts and structures are of obvious advantage

to the species and nothing but natural selection is required for their evolution.

Characters concerned with the care of offspring are, of course, preponderatingly female. It is therefore interesting to note some cases in which the heavier burden in this respect falls upon the male.

The male stickleback is brightly coloured with red and blue. In the breeding season he constructs a nest of weeds. He then collects one or more females, tackling any competing males with the sharp spines of his back. His task is now to induce the females to enter the nest and deposit their eggs. This achieved, he fertilizes them and mounts guard over them. His chief adversaries in his protracted watch are the very females which laid the eggs. When the eggs grow into little fishes he still tends them, sucking them into his mouth if danger threatens.

Paternal care of this sort is also shown by several species of toad. But it is in certain birds that the reversal of the roles of the sexes is carried furthest. In the phalarope, a northern wading-bird, the male is smaller than the female and less brightly coloured. The female is more active than the male in courtship, and it is the male which incubates the eggs and takes care of the young.

SEX CHARACTERS NOT CONCERNED WITH REPRODUCTION

There is yet another type of sex character, namely, the type which is concerned neither with sexual congress nor yet with the care of offspring. This is a type of sexual difference which is but rarely met with. A very good

example is afforded by the Huia, a bird peculiar to New Zealand (Fig. 9). Both sexes feed chiefly upon the grub of a timber-boring beetle. The short, straight beak of the male is adapted to chiselling away decaying wood, while the long curved beak of the female serves to pick grubs from holes in sound wood, which the male would be unable to attack. The sexes are said to assist one another in their search for food. Here we have a sexual difference concerned only with the capture of food. It is an example of division of labour between the sexes in a matter not concerned with sexuality.

CLASSIFICATION OF SEX CHARACTERS

In order to present the facts and theories dealt with in this chapter in a manner in which they may be readily appreciated, I have prepared a diagram (p. 45) showing my classification of sexual characters, with one or two examples illustrating each category. The reader will notice that I have not adopted the old doctrine of dividing sexual characters into primary, accessory and secondary sexual characters. I disagree with that classification because there is no real distinction to be drawn between the accessory and the secondary characters.

It will be evident to the reader that characters in category A evolved by natural selection, and characters in category B by sexual selection. Category B 1 is to be accounted for on the "choice" theory, category B 2 on the "combat" theory. ^a

It is no objection to my classification that certain char-

acters (*e.g.*, antlers) appear in more than one place (A 3a and B 2). This double appearance points clearly to the fact that two separate agencies have been at work in their evolution. Indeed, this process of splitting the causes at work in the evolution of characters could be carried further still. For instance, the breasts of woman, which I have scheduled only in category A 3a, are of such æsthetic importance that they should almost certainly be included also in category A 2a (2) or B 1.

The reader should note that sex characters are not *necessarily* sex differences. Sometimes the same bright colours appear in the breeding season in both male and female, to stimulate the sexual emotions of the opposite sex. Many birds, such as the grebe and heron, illustrate this point. In mankind the pink cheeks, the red lips, and the shapely contours of the body are sexual characters shared by both sexes.

" HETEROGONY."

One point of general interest remains to be mentioned, concerning the size attained by the less essential of the sex characters compared with that of the whole body.

If one takes a large number of beetles of the same species and measures the length of the body of each as well as the length, for instance, of a joint of one of the legs, one finds that whether a given beetle be large or whether it be small, the joint is of proportionate size—say one-third of the total body length.

But if one measures not an essential organ such as the leg

but a much less essential organ such as the mandible or "horn" of the male stag-beetle, and compares it with the length of the body, one finds that it is not of proportionate length in different cases. The larger the body, the larger the horns relatively to the body (Fig. 10). In small stag-beetles, the horns are considerably less than one-half of the length of the rest of the body; in large specimens they are about two-thirds of the body length.

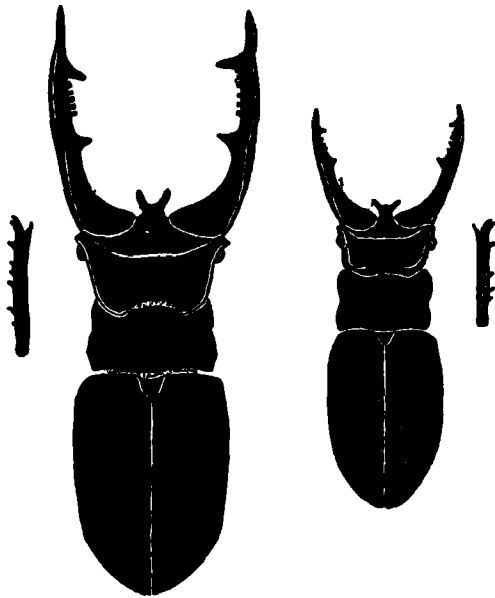


FIG. 10.--A LARGE AND A SMALL STAG-BEETLE, TO ILLUSTRATE "HETEROGONY." NATURAL SIZE. BESIDE EACH BEETLE IS DRAWN THE "TIBIA" (FOURTH JOINT) OF ITS FIRST LEG. IN EACH BEETLE THE TIBIA IS RATHER MORE THAN ONE-THIRD OF THE BODY-LENGTH. THE "HORNS" ON THE OTHER HAND ARE RELATIVELY LARGER (NEARLY TWO-THIRDS THE BODY LENGTH IN THE LARGER BEETLE, AND RELATIVELY SMALLER (LESS THAN ONE-HALF THE BODY-LENGTH) IN THE SMALLER BEETLE.

This "disharmony" or "heterogony" is of wide occurrence in those sexual characters which are not of very great

importance. Parts which are immediately concerned in the passage of sperms from the male to the female are not disharmonic. "Heterogonic" growth is an easy method by which sexual differences may arise.

CONCLUSION

The sexual characters may be grouped as useful or useless to the species concerned. The first group includes the gonads and the various characters concerned with bringing the sperms in contact with the eggs and with the care of offspring, as well as a few characters of rare occurrence which are unconnected with reproduction. The second group includes such characters of adornment, offence, and defence as have evolved by sexual selection, that is by competition by members of one sex (nearly always the male) for possession of members of the other. Sexual selection was formerly thought to account for many apparently useless characters which in reality are useful.

The less important sexual characters often grow more rapidly than the rest of the body, and are therefore relatively larger in large than in small individuals.

SEX CHARACTERS

45

CLASSIFICATION OF SEX CHARACTERS.

| | EXAMPLES. | |
|--|---|---|
| | <i>In the male.</i> | <i>In the female</i> |
| A.—CHARACTERS USEFUL TO THE SPECIES | Testes | Ovaries |
| 1. The gonads | | |
| 2. Characters concerned in the transmission of sperms from male to female | | |
| a. Physical characters | | |
| 1. Physically necessary or advantageous | Vas deferens. Copulatory organ (in part) | Vagina |
| 2. Psychically necessary or advantageous | Copulatory organ (in part). Ornaments of most male animals. Beauty in man (in part) | Bright colours of female phalarope. Beauty in woman (in part) |
| b. Psychical characters | Mating instinct. Display instinct | Mating instinct. Display instinct when present in female |
| 3. Characters concerned in the care of offspring | | |
| a. Physical characters | Strength. Antlers (in part) | Womb. Breasts |
| b. Psychical characters | Instinct to protect female and young | Maternal instincts |
| 4. Characters not concerned in transmission of sperms nor in care of offspring | Short straight beak of male Huia | Long curved beak of female Huia |
| P.—CHARACTERS NOT USEFUL TO THE SPECIES | | |
| 1. Characters of adornment evolved by sexual selection | Ornaments of polygamous birds (e.g., ruff) (in part). Beauty in man (in part) | Beauty in woman (in part) |
| 2. Characters of offence and defence evolved by sexual selection | Antlers (in part). Spurs. Manes (in part) | |

CHAPTER III

THE SEX CHROMOSOMES

INTRODUCTION

So much undiluted nonsense has been written on the subject of sex determination, that very probably the average man or woman has no idea that the most basic part of the problem has been solved. Some of the superstitions and futilities concerned with this matter are so entertaining and illustrate in such a delightful manner the heroic way in which the non-scientific mind tends to generalize from quite obviously insufficient data, that I have thought it worth while to devote a part of Chapter IX to a consideration of them.

But before we leave the realms of common sense and dive headlong into the sea of falsehood in which the editors of our periodical press delight that their readers should bathe, let us consider the facts of the case as laid bare by those who investigate first and make theories afterwards.

In the first part of this chapter we shall discuss what it is that determines that one egg grows up into a male whereas another egg grows up into a female. We shall reserve for Chapter IX the problem of how the natural process of sex determination may be artificially controlled. Suffice it to say at this point that it is quite absurd for

anyone to imagine that he can devise a method of artificial sex control unless he understands how sex is determined in nature. In the second part of the chapter we shall deal with problems of inheritance in relation to sex.

THE DETERMINATION OF SEX BY THE CHROMOSOMES

When I spoke of the chromosomes in the first chapter, I said that in any one species every cell (except the germ cells) in the body of every individual has the same number of chromosomes. In a footnote I mentioned that this statement was not quite exact. Its slight inexactitude is the key to the determination of sex.

The following is a generalized account of the matter, which does not apply strictly to all animals but which introduces the essential features.

The male has one less chromosome than the female in each cell in his body. Suppose the female has five pairs of chromosomes; then the male has four pairs of chromosomes and one unpaired chromosome. The four pairs of the male correspond with four of the five pairs of the female. The odd chromosome of the male corresponds with the remaining pair of the female. The odd chromosome in the male and its corresponding pair in the female are called the sex chromosomes.

One sex chromosome determines maleness; two sex chromosomes determine femaleness. Let us see what evidence there is for the truth of this statement. Let us consider whether one sex chromosome is the cause or the result of maleness, and two of femaleness.

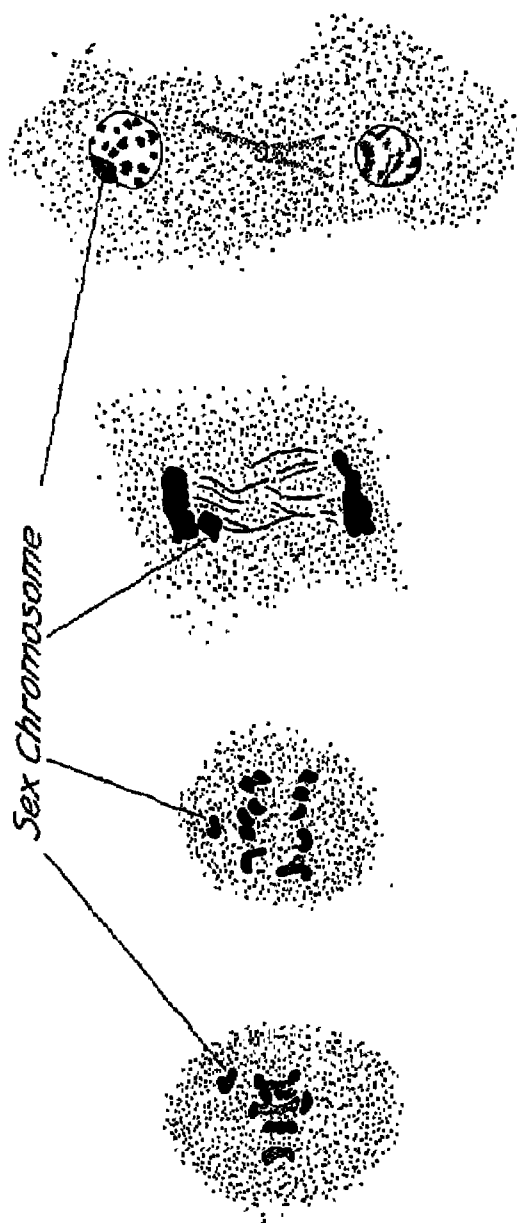


FIG. 11.—THE "REDUCING DIVISION" OF A GERM CELL OF A MALE CRICKET, SHOWING THE SEX CHROMOSOME, HIGHLY MAGNIFIED.

- A.—The ordinary chromosomes are arranged in the middle of the cell. The single sex chromosome has already passed towards one pole.
- B.—The ordinary chromosomes have separated partner from partner to form a group at each pole of the cell.
- C.—The ordinary chromosomes are fusing together to form nuclei. The sex chromosome remains separate from them.
- D.—The ordinary chromosomes have resolved themselves into nuclei. The sex chromosome is seen attached to one of the nuclei. The sperms derived from the cell containing the sex chromosome will be female-producing sperms; those derived from the cell containing no sex chromosome will be male-producing.

It will be remembered that the cells which give rise to the germ cells undergo a peculiar division during which the chromosomes do not divide but separate partner from partner. What happens to the odd sex chromosome of the male, which has no partner ?

It goes either into one cell or into the other cell at the "reducing" division, and thus two cells are formed, one having one sex chromosome, the other having no sex chromosome (Fig. 11). Thus two types of sperms are formed in equal numbers, one with and one without a sex chromosome.

In the female the matter is simple. At the peculiar division the pair of sex chromosomes behaves exactly as do the other pairs of chromosomes ; one partner goes to one cell, one to the other. Thus each egg contains one sex chromosome.

It follows that an egg, containing one sex chromosome, may be fertilized *either* by a sperm bearing *one* sex chromosome, in which case it comes to have two sex chromosomes ; *or* it may be fertilized by a sperm bearing *no* sex chromosome, in which case it has only one sex chromosome. In the former case it grows into a female, in the latter into a male. It is not easy to deny that there is a casual relationship between one sex chromosome and maleness and between two sex chromosomes and femaleness.

As was mentioned before, this is only the ground-plan of sex determination : various minor modifications exist. In many animals, for instance, the sex chromosome of the male has a small but inert partner, and in others its partner

is as large as itself but inert.* Another exception occurs in the case of birds and moths. Here the mechanism of sex determination is the same, but one sex chromosome makes for femaleness and two for maleness.

It sometimes occurs in the fruit-fly that when an egg matures and goes through the reducing division, the two sex chromosomes do not separate from one another in the normal manner, one going into each cell, but they stick together so that one cell has no sex chromosome and the other has two. Thus two abnormal sorts of eggs are formed, with no sex chromosome and with two sex chromosomes respectively, instead of the normal one sex chromosome. The abnormal egg with no sex chromosome dies if fertilized by a sperm carrying no sex chromosome.† But if it is fertilized by a sperm carrying a sex chromosome, it comes to have one sex chromosome; and thus it grows up to be a male though the sperm concerned in its conception was really a female-determining sperm! The abnormal egg with two sex chromosomes dies if fertilized by a sperm carrying a sex chromosome; the balance between the sex chromosomes and the other chromosomes is upset.‡ But if it is fertilized by a sperm carrying *no*

* The "inert" partner is called the "Y chromosome." The other sex chromosomes, of which the male has one, and the female two, are called "X chromosomes." In this book I have purposely disregarded the Y chromosome, because so little is known of its function and because the story of sex determination, as far as it is at present known, can be more easily told without reference to it. As a matter of fact, recent research has shown that it is not always so inert as has been imagined, but the time has not yet come when a useful account of it can be given. *Wherever I speak of "sex chromosomes," I mean "X chromosomes."*

† *i.e.* actually carrying a Y chromosome. See footnote above.

‡ We shall see in a later Chapter that an animal can live with three sex chromosomes provided that the other chromosomes are also present in triplets instead of pairs.

sex chromosome, it still has two sex chromosomes ; and thus it grows up to be a female though the sperm concerned in its conception was a male-determining sperm ! A more perfect example of an exception proving a rule cannot be imagined. The exception—namely, that a male-producing sperm occasionally produces a female and vice versa—literally *proves* the rule that one sex chromosome determines maleness and that two determine femaleness.

Although in the vast majority of animals sex is determined by the sex chromosomes, yet individuals of each sex have the potentiality of developing under special circumstances into individuals of the other sex. This is shown clearly by experiment and by freaks of nature, as will be told in later chapters. That females possess male characters in a latent condition and transmit them is also proved by breeding together different species of animals. In pheasants, for instance, the males of the various species are very different from one another, but the females are very similar. If a female of species A be mated with a male of species B, her sons will be intermediate in character between males of species A and males of species B. In other words, the female has transmitted the male characteristics of her species to her sons, though she never showed them herself.

We must regard the chromosome mechanism of sex-determination as we regard a railway switch. A simple movement of a lever decides whether a train shall go in one direction or another. The actual lines are already laid out ; all the switch does is to decide along which the train shall pass. The sex chromosomes provide a switch mechanism which sends the organism either along the

complicated journey which leads to maleness or along that which leads to femaleness.

PECULIARITIES OF SEX DETERMINATION IN BIRDS AND MOTHS

In birds and moths an opportunity arises for sex to be determined in a way rather different from that in which it is determined in other animals. In order to understand this matter we must first be familiar with the ripening of an ordinary egg.

When an ordinary egg is fully grown, it undergoes the peculiar "reducing" division in which the number of chromosomes is halved. But in this division the egg does not divide into two smaller eggs, for this would mean that each egg was insufficiently provided with reserve food-material; on the contrary, it merely buds off a minute round cell containing the unwanted chromosomes, and remains practically as large and as rich in yolk as ever. The minute round cell, which is called the polar body, is of no further use and decomposes and disappears.*

Now in birds and moths, unlike all other animals yet investigated, it is the female that has one sex chromosome, whereas the male has two. When the first polar body is formed, the sex chromosome may either remain in the egg, or it may pass out into the polar body and be lost. Thus there are two types of egg, male-producing (with one sex

* Another similar "polar body" is then formed, which also decomposes; but in its formation the chromosomes each divide as in ordinary cell-division, and no further reduction of their number occurs. For the purpose of understanding the problem of sex-determination in the pigeon, only the first polar body need be taken into consideration.

chromosome) and female-producing (with no sex chromosome). All sperms are the same and contain one sex chromosome.

It is obvious that if any circumstance could make the sex chromosome stay in the egg rather than pass out into the polar body, that circumstance would determine maleness. Similarly, any circumstance causing the sex chromosome to pass into the polar body would determine femaleness. These conditions are realized in the pigeon.

Pure uncrossed species of pigeons have this peculiarity, that they lay two eggs in a clutch, and that normally the first of the two is small and turns into a male, while the second is large and turns into a female. The first, smaller egg contains relatively more water than the second, and it is poorer in reserve food-materials. The most probable explanation of the facts is that when the smaller egg forms its polar body, its chemical nature in some way determines that the sex chromosome shall stay within the egg ; whereas when the second, larger egg undergoes its reducing division, the conditions favour its extrusion into the polar body. We shall see in a later chapter that in moths it is possible to control the direction of movement of the sex chromosome at the reducing division by change of temperature, and thus artificially alter the sex ratio.

It is evident that although pigeons agree with other animals in that the sex chromosomes determine sex, they differ from other animals in that the chemical constitution of the egg and not chance decides how many sex chromosomes shall be present to determine it. The chemical constitution of the egg is here the primary means of sex-determination.

A CASE IN WHICH SEX IS NOT DETERMINED BY SEX
CHROMOSOMES

In a few animals sex chromosomes play no part in the determination of sex. The marine annelid *Bonellia* is the best known case.

The female *Bonellia* (Fig. 12) is an oval animal of the size of a plum, with a long proboscis projecting from her front end. She is one million times as large as the male of her species. The latter lives within the excretory organ of his wife, and is wholly dependent on her for food. But the marital relations of *Bonellia*, unusual though they are, are not more aberrant than the method by which sex is determined in this animal.

The very young *Bonellia* attaches itself to the proboscis of a fully-developed female if it comes across one during its free-swimming larval life. Passing down the proboscis "into the mouth, *it develops therein into a male*. When fully developed it crawls out of the mouth and over the surface of the female's body till it comes to the opening through which both excretory products and fertilized eggs are shed to the exterior. It passes through this opening into the excretory organ and remains there throughout life, fertilizing the eggs as they pass by on their way to the exterior.

But if the larval *Bonellia* fails to find a female, it grows up solitarily on its own account ; *and it grows up to be a female. Sex is determined by whether or not it chances to find a female at the appropriate time.*

It is found that the organs of a young *Bonellia* differentiate more slowly if it is attached to the body of a

female than if it is solitary. It is probable that in *Bonellia* slow differentiation makes for maleness and rapid differentiation for femaleness.

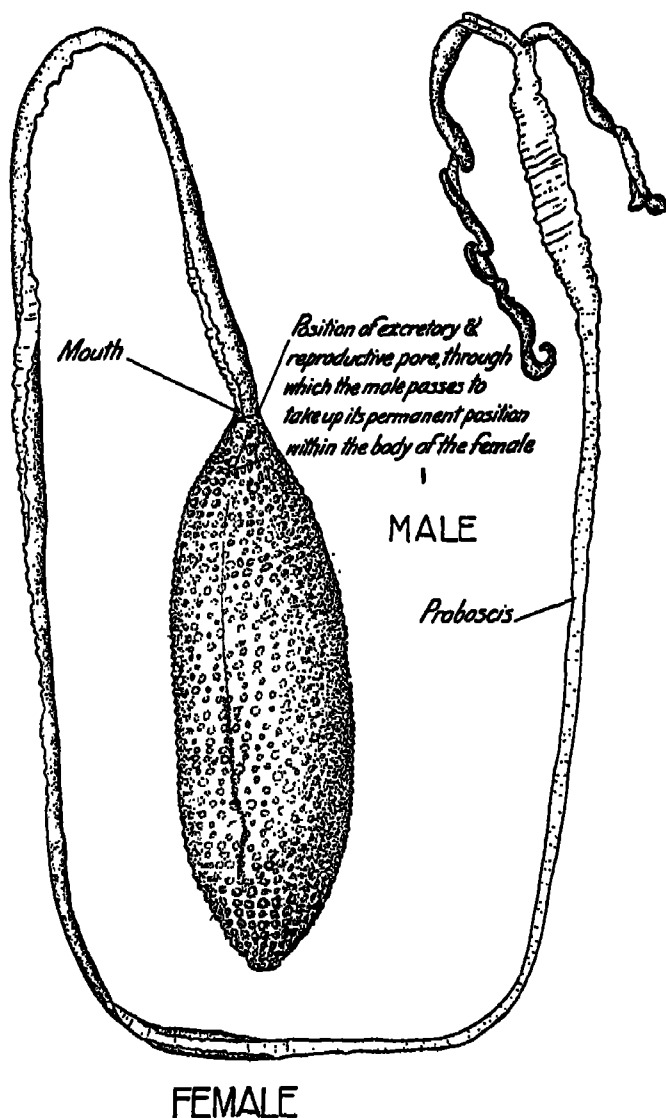


FIG. 12.—*BONELLIA*, MALE AND FEMALE. NATURAL SIZE.

HEREDITY

The sex chromosomes have other functions besides the determination of sex, for they carry factors just as the other chromosomes do. Most of the factors carried by the sex chromosomes have nothing to do with sex. In the fruit-fly, the sex chromosomes carry factors concerned with eye-colour, with eye-size, with wing-shape, with wing-size, with body-colour and with many other characters as well. None of these are sex characters. But because they are inherited through the agency of the sex chromosomes, and because the sex chromosomes differ from all other chromosomes in that the male has only one instead of a pair, the way in which they are inherited is different. This cannot be appreciated until something is known of ordinary inheritance.

The study of inheritance resolves itself into the study of the inheritance of variations. No two individuals are precisely alike. The geneticist studies what offspring are produced when two different individuals are mated together.

For a long time little progress was made with this study, because people were trying, without knowing it, to solve problems of immense complexity. They were studying the inheritance of characters in the development of each of which a large number of "factors" was concerned.

To a monk, Gregor Mendel, belongs the credit of having first studied the inheritance of "unit-characters".* In the garden of his monastery at Brünn he crossed varieties

* The term "unit-character" is looked upon with disfavour nowadays for more than one reason, but for our purpose it is not objectionable.

of the edible pea with one another. He chose seed colour as one of the characters on which to base his experiments.

Now in the make-up of nearly every character a large number of factors is concerned. In such matters as size and fertility it has been shown that many factors are concerned, some probably in one chromosome, some in another. The result is that no clear-cut results are obtained. It was because Mendel's green peas differed from his yellow ones in but a single pair of factors that he laid the foundation of the important branch of biology that bears his name. Mendelism is now at last beginning to solve the problem which confronted the early geneticists before unit-factors were understood—the inheritance of characters in whose development a large number of factors is concerned, the effect of each of which is very small. These problems would never have been solved without the conception of unit-factors.

Every organism has a double set of factors, simply because it has a double set of chromosomes. Take any unit-character in any organism.* There are *two factors influencing it*. These two factors may be the same, or they may be different, *i.e.*, each trying to produce different results. If the two are different, usually one of them wins, that is, it is "dominant" over the other. The weaker is called the "recessive" factor.

To understand this, let us mate a pure-bred grey-bodied fruit-fly with a pure-bred black-bodied one. We may denote the factor for grey body-colour as "G," and for

* Except a sex-linked character. See later in this Chapter.

black body-colour as "B." Then we may represent our cross as :—

$$\begin{array}{ccc} \text{GG} & \times & \text{BB} \\ \text{Grey} & & \text{Black} \end{array}$$

each individual having two factors for body-colour, because each received one factor from each of its parents.

Now what types of germ cell will each form? We know that at the peculiar division of the cells which are going to produce gametes the pairs of chromosomes separate partner from partner, one going to each cell, so that each gamete has one chromosome of each pair. *So each gamete has one factor of each pair.* So now we may write :—

$$\begin{array}{ccc} \text{GG} & \times & \text{BB} \\ \text{Gametes } G & & B \end{array}$$

These two types of germ cell, uniting, give GB :

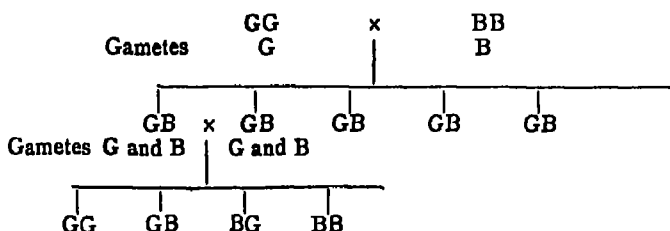
$$\begin{array}{ccccccc} \text{GG} & \times & \text{BB} \\ \text{Gametes } G & & B \\ \hline & & | & & & & \\ \text{GB} & & \text{GB} & & \text{GB} & & \text{GB} & \text{and so on.} \end{array}$$

Thus all the offspring are of the constitution GB. Now grey body-colour "dominates" over black body-colour, so that the hybrid appears grey, though actually it carries both factors.

Now what happens when a GB fly is mated with another of the same brood? First of all, what gametes does a GB fly form? The two factors separate from one another at the peculiar division, and thus two sorts of germ cell are formed, G and B :—

$$\begin{array}{ccccccc} \text{GG} & \times & \text{BB} \\ \text{Gametes } G & & B \\ \hline & & | & & & & \\ \text{GB} & & \text{GB} & & \text{GB} & & \text{GB} \\ \text{Gametes } G \text{ and } B & \times & G \text{ and } B & & & & \end{array}$$

Now a G sperm has equal chances of fertilizing a G egg or a B egg, and a B sperm has equal chances of fertilizing a G or a B egg ; so that the individuals formed are GG, GB, BG, and BB, in equal numbers :—



The first is a pure grey ; the second and third are hybrids, appearing grey ; the fourth is a pure black. Thus we get the ratio three greys to one black in the second generation.

The facts may be summed up as follows. If we mate a dominant with a recessive, the offspring all show the dominant character. If we mate the offspring together the next generation consists of individuals showing the dominant character and individuals showing the recessive character in the proportion of three to one.

THE INHERITANCE OF SEX-LINKED CHARACTERS

Now let us consider what happens when a sex-linked character is concerned, that is, a character in whose transmission the sex chromosomes are concerned. Red eye-colour (R) versus white eye-colour (W) in the fruit-fly will serve as an example. The red eye-colour is the normal colour characteristic of the species.

Let us mate a white-eyed female with a red-eyed male.

The white-eyed female has two sex chromosomes, and is WW, *but the male has only one, and is R.*

$$\begin{array}{ccc} \text{WW} & \times & \text{R—} \\ \text{White-eyed female} & & \text{Red-eyed male} \end{array}$$

The female's eggs are all of the constitution W, but the male forms two sorts of sperms, namely those with a sex chromosome, and those not carrying a sex chromosome; in other words, those carrying R and those not carrying R, thus :—

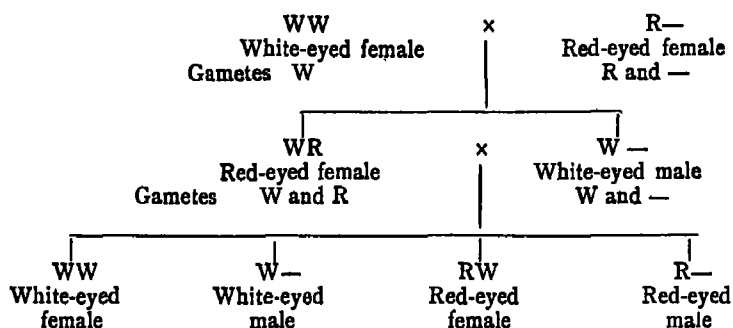
$$\begin{array}{ccc} \text{WW} & \times & \text{R—} \\ \text{Gametes} \cdot \text{W} & & \text{R and —} \end{array}$$

Random mating of the eggs with both types of sperm gives WR and W— individuals in equal numbers. WR individuals are female because they have two sex-chromosomes and are red-eyed because red is dominant over white. The W— individuals are males through having only one sex chromosome and are, of course, white-eyed :—

$$\begin{array}{ccc} \text{WW} & \times & \text{R} \\ \text{Gametes} \quad \text{W} & & \text{R and —} \\ \hline \text{WR} & & \text{W—} \\ \text{Red-eyed female} & & \text{White-eyed male} \end{array}$$

It will be noticed that "criss-cross" inheritance has taken place; *the sons resemble their mother and the daughters resemble their father.* This may account for the special resemblances often noticed in mankind between mother and son and between father and daughter. These resemblances may be due to factors that are sex-linked, that is carried in the sex chromosomes.

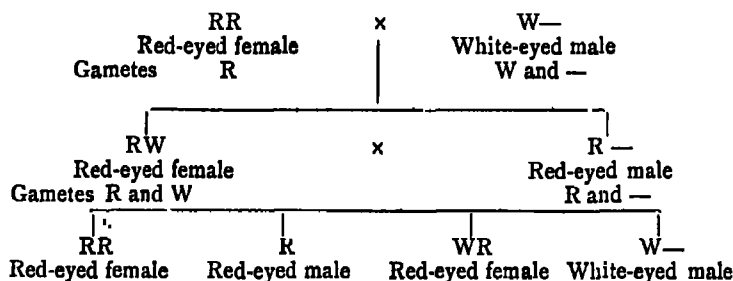
If individuals of the first generation are crossed together, the result is as follows :—



The reader will observe how entirely different this is from what occurs in the inheritance of a character which is not sex-linked. The difference may be summarized as follows :

| | Ordinary Character | Sex-linked Character (the mother showing the recessive character) |
|-------------------|------------------------|---|
| First generation | All offspring the same | I : I |
| Second generation | 3 : I | I : I |

If we mate a *red-eyed female* with a *white-eyed male* (the reverse of the cross just described), then all the offspring are red-eyed ; and if the offspring are mated together, they produce three red-eyed offspring to one white-eyed. It is precisely like the inheritance of an ordinary (not sex-linked) character, *except that all the white-eyed offspring are males*. The reason for this will be clear to anyone who cares to glance at the following diagram :



In mankind several sex-linked characters are well known. Colour-blindness, night-blindness and hæmophilia are examples. Night-blind people cannot see in twilight. In hæmophilia the blood will not clot readily, so that sufferers are apt to bleed dangerously from slight wounds. The factors for these characters are situated in the sex chromosomes, and they are inherited like white eye-colour in the fruit-fly.

In the fruit-fly, a white-eyed male produces only normal (red-eyed) offspring, if mated with a normal (red-eyed) female. But if their female offspring are mated with any normal male *half their sons will be white-eyed*. Their male offspring, on the other hand, do not transmit the peculiarity to any of their offspring, simply because they have not got a factor for it; as far as white eyes or red eyes are concerned, they obtained their heritage only from their (red-eyed) mother. In *precisely* the same way a colour-blind man, married to a normal wife, has only normal children. But no matter whom his daughters marry, *half their sons will be colour-blind*. His sons, on the contrary, have no colour-blind children at all.

A question about colour-blindness yet remains. Why are men so much more frequently colour-blind than women? The answer is that one factor for colour-blindness is sufficient to make a man colour-blind, because he has only one sex chromosome. On the other hand, two factors for colour-blindness are necessary to make a *woman* colour-blind, because she has two sex chromosomes, and hence two factors are concerned with colour-blindness or the reverse; and if one of these factors is the normal one (*i.e.*, the reverse of colour-blindness) it dominates over the other and the individual is normal.

Put in another way, the matter stands as follows : A man may be colour-blind if only his mother has a factor for colour-blindness, because he gets his single sex chromosome from his mother only ; but a woman gets one of her sex chromosomes from each of her parents, and therefore she gets one normal sex chromosome unless both parents carry a factor for colour-blindness. A colour-blind girl can only be produced when a colour-blind man marries a woman of a colour-blind family.

CONCLUSION

In most animals two sorts of sperms are produced in equal numbers, possessing no sex chromosome and one sex chromosome respectively. The former give rise to males, the latter to females. In birds and moths the sperms are all alike, but there are two sorts of eggs ; and the chemical composition of the egg may determine sex by determining in which direction the sex chromosome moves when the polar body is formed. In *Bonellia* sex is determined not by sex chromosomes, but by environment.

The various characters (such as colour-blindness) whose factors are carried by the sex chromosomes are necessarily inherited in a peculiar way.

CHAPTER IV

SEX HORMONES

INTRODUCTION

THERE exist in the bodies of the higher animals certain glands called ductless glands, which have no tube to carry off their secretion. The secretions of such glands pass directly into the blood, dissolve in it, and get carried to all parts of the body. A hormone may be defined as a substance secreted into the blood by a ductless gland, which has a specific influence on some part of the body. Such influence may be of an immediate kind, causing some change to take place at once ; or it may be a slowly-acting influence, causing the part concerned to grow more rapidly, more slowly, or in a special way. It is with slowly-acting hormones that we are concerned in this chapter.

A familiar example is the thyroid gland, which is situated near the voice-box in the throat. It has a profound effect on the general well-being of the body. If it is removed or diminished by disease, the vital processes take place much more slowly, so that the individual becomes slow in thought, speech and movement, and develops an excess of fat. If the gland is deficient at birth, the individual is called a "cretin." A human cretin aged fifteen may resemble a child of two years in size and mentality.

Another ductless gland is the pituitary, which is situated

below the brain. Its hormone encourages growth of the bones, and if a tumour appears upon it in adult life, the face, hands and feet increase in size. If the pituitary is similarly affected early in life the individual becomes a giant. The hormone secreted by the pituitary has many other effects as well.

The interest of these glands for us is that the testis and the ovary of the higher animals secrete hormones, whose function it is to call forth the development of the characters of the appropriate sex. This is shown by the fact that if the testis or ovary is removed, many sexual characters are not developed ; or, if they are already developed, many of them regress.

In insects, however, this is not the case. For instance, if the testes of a caterpillar be removed, the moth to which that caterpillar gives rise has all the characters of the male sex except the testes themselves ; and the same applies to the female sex when the ovary is removed.

In this chapter we shall study the effects of removing the testes and ovaries of the higher animals and of transplanting them. First we shall deal with the removal of the testes.

CASTRATION

Castration has for a long time been practised on male domestic animals in order to render them less ferocious and more easily fattened. It has also been practised by certain religious sects in mankind. The effects of castration are much more marked if the operation is performed early in

life, before the sex characters are fully developed, than if it is performed after puberty; and there is little doubt that the effects would be extremely striking if it were possible to castrate an embryo.

If a boy be castrated before puberty, he grows up differing in many points from a normal man and approximating to an asexual type. He has no beard. His voice remains that of a boy because his voice-box never enlarges. Fat tends to accumulate in various parts of his body, and his long bones do not stop growing when they should, so that he becomes lanky of limb. The hair in the pubic region resembles that of a woman in its disposition more closely than that of a man. The penis is very small, and erection occurs only in rare instances. The sexual instinct is seldom developed. Various glands in connection with the internal reproductive organs are undeveloped.

If castration is performed after puberty, the same abnormalities result, but to a lesser degree. The beard disappears, the voice becomes high-pitched, and the sexual instinct gradually but generally completely vanishes.

In just the same way castration in other mammals results in a reduction of the penis and various glands, in the accumulation of fat, in greater growth by certain of the long bones, and in loss of the sexual instincts. The tendency to fight other males and to copulate with females in heat is never developed or is lost.

The effect of castration on horned animals is often very noticeable. In some breeds of sheep, both sexes are horned; in others, horns are confined to the male sex. Castration has no effect on rams of the former breeds, but young rams of the latter breeds never develop horns if

castrated. Much the same state of affairs exists in deer, but the matter is slightly complicated by the fact that the antlers are shed annually. Castration has no effect on reindeer, in which species both sexes carry antlers. If a stag of any other species is castrated early, the antlers never appear. If it is castrated rather late, when the antlers have begun to grow but before the "velvet" has been shed, they never develop properly. The velvet remains covering them, and they are small and misshapen. Such antlers are called "peruke" antlers and are never shed. If a stag with fully developed antlers is castrated, his antlers are soon thrown off and are never replaced, or are replaced by peruke antlers.

In birds the conditions are rather different from those in mammals, for castration is *not* followed by a reduction of all the male characters. If a young cock is castrated (an operation often performed by poulterers) the "capon" so produced retains the plumage of the male. Indeed, his tail feathers may even be longer and shinier than those of a normal male. His spurs, also, are normally developed, but his comb is very small indeed; it is smaller than a female's. After castration it grows at the same rate as the rest of the body, whereas normally it grows very much faster in the male and slightly faster in the female. Other changes after castration are a marked increase in the amount of fat, an enlargement of the pituitary gland, and a reduction or complete disappearance of the vas deferens. As regards behaviour, the tendency to fight with other cocks, to crow, and to copulate with hens is never developed if castration is performed early or is lost if it is performed late.

Particularly interesting is the result of castration of male

Sebright bantams. Sebright bantams are peculiar in that the male has the same plumage as the female. When a male is castrated, he proceeds to develop male plumage ! The testis of the Sebright does something which the ovary of an ordinary bird does ; for, as we shall see later, the ovary of birds prevents the assumption of male plumage.

The effects of castration on reptiles have not yet been studied. Among amphibians, the frog and the newt have been castrated, and the testis has in each case been shown to be responsible for the production of many male sexual characters. Castration of the frog results in the loss or failure to develop of the pigmented glandular patch on the index finger which serves to hold the female during copulation, and of the instinct to croak and to clasp the female. Further, the arm muscles and the bags for the storage of sperms fail to enlarge.

The male newt resembles the female during the greater part of the year, but in the breeding season he is characterized by the bright colours developed on the sides of the body, by the crest which runs along the back and tail, and by the great swelling of the " cloacal " region—that is, the region where the alimentary canal and the reproductive tubes open to the exterior.

Ordinary castration results in the loss of these characters. It might be objected, however, that their loss might be due to the operation as such, for the male sex characters of the newt are readily lost as a result of operative shock. So another method of castration was tried, to eliminate this source of error. It was found that starvation resulted in the reduction of the testes to a minute size and the loss of the sex-characters. Accordingly newts which had been

starved were well fed until they were of the same size as before starvation commenced. The testes did not grow again, and the sex characters were not developed. It must be concluded that the testes are necessary for the development of the male sex characters in the newt.

It also appears that in certain male fish the annual development of bright colouration is under the influence of the testes. In such lowly animals as the earthworm and the flatworm there is evidence that the testes are not without effect on remote parts of the body.

OVARIOTOMY

Having reviewed the effects of castration on the male, it now devolves upon us to consider what happens when the ovary is removed from a female. This operation is known as ovariectomy. It is practised by some farmers on pigs in order to prevent the occurrence of "heat," because during the period of heat the animal is supposed not to put on so much weight as at other times. The operation is a cruel one and appears to be quite unnecessary. There exists a savage tribe which practises ovariectomy on girls, and in various diseases the ovaries are removed from women.

The result of ovariectomy in women is that menstruation ceases, and the vagina, and more particularly the womb, undergo reduction in size. Fat tends to accumulate, and hair may begin to grow above the corners of the mouth and on the chin—that is, where it sometimes grows in old women and in old men who have been castrated. The sex instinct is usually decreased.

In other mammals comparable changes take place. The decrease in the size of the womb is most striking. The udder of the cow is not properly developed if ovariectomy is performed early. Heat does not occur after ovariectomy. Ovariectomy does not affect horns in such female mammals as possess them.

In birds, ovariectomy results in an individual very similar to a capon. It is difficult to say whether a bird is a capon, or an ovariectomized hen, or a hen in which the ovary has disappeared owing to disease (Fig. 18). After ovariectomy the spurs grow* and the plumage becomes that of a cock, but the comb dwindles. The oviduct, the tube by which the eggs would have escaped to the exterior, becomes infantile, and no sexual instinct persists.

It is evident that the ovary inhibits the assumption of male plumage. Just how it does this is uncertain. Perhaps it secretes a hormone which has an inhibiting effect: perhaps it secretes no hormone, but takes from the blood a substance necessary for the production of male plumage.

In animals lower than birds the results of ovariectomy are less well known, and no very useful purpose would be served by my reciting them here. Let us generalize from the data already given, and review the theories to which they have given rise.

THE EVOLUTION OF THE CONTROL OF SEX CHARACTERS BY HORMONES

In the higher animals the tendency of castration on the one hand and of ovariectomy on the other is to produce one

* This statement has recently been contradicted.

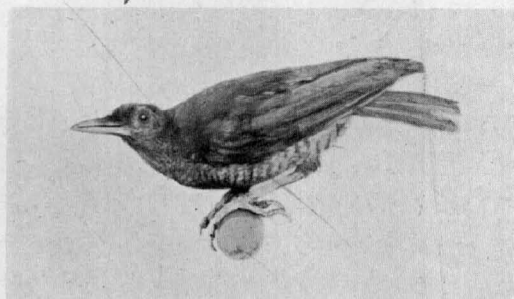
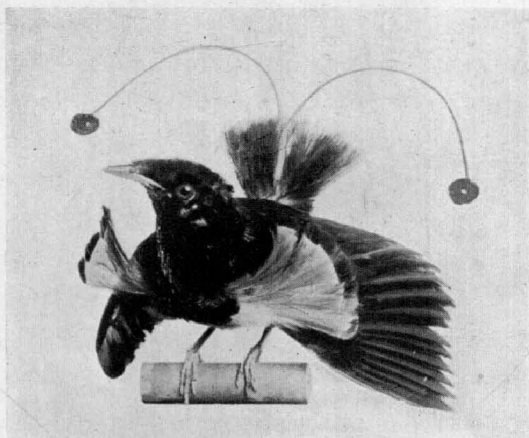


FIG. 8. Male and female birds of paradise (*Cincinnurus regius*). The male is above. (Photo by Mr. A. Robinson)



FIG. 9. Male and female Huia (*Heteralocha gouldi*). The male has the short, straight beak. (Photo by Mr. A. Robinson)

[see p. 41]

and the same type of individual. The earlier the operation is carried out, the more completely is this type of individual realized. Pushed to its logical conclusion, this means that if the embryo were castrated or ovariectomized directly the testes or ovaries appeared, there would result a type of individual which would be precisely the same whether it were originally a male or whether it were a female. In mammals this individual would be nearly* non-sexual. It should be noted that in mammals castration does not result in the assumption of any female character,† but only in an approximation to a non-sexual type to which the ovariectomized female also tends. Thus the loss of the deep voice and beard of the male can as well be ascribed to a return to a juvenile, non-sexual, as to a female condition.

The hypothesis of the non-sexuality of the early castrate has given rise to the theory that in the higher bony animals, any character which separates the sexes but which nevertheless develops despite early castration or ovariectomy, was not originally a sexual character at all, but was shared by both sexes in the primitive ancestors and subsequently dropped out in one sex in the course of evolution. It appears to me that to accept this doctrine is to fall into the enticing error of arguing about the ancestral history of a species from what is known of the development of an individual of that species. The domestic fowl is a splendid case in point. Here ovariectomy results in definitely male characters—the bright plumage and the spurs of the cock. Those who uphold the view that any character which

* I say "nearly," because a mammal would retain the nipples characteristic of the male, which are the rudiment of an essentially female character.

† Perhaps the distribution of fat and pubic hair tends to the female condition.

develops in the absence of ovary and testis is a character which was shared by both sexes in the ancestors, must hold that both sexes in the ancestors of the fowl were brightly coloured, with long curved tail-feathers and spurs. There is no probability nor any shadow of evidence that such was the case.

The correct way to view the matter is probably as follows:—In the most primitive animals each cell developed in the male way if it had one sex chromosome, or in the female way if it had two. This is precisely what obtains in insects. Subsequently, certain characters evolved which would only develop under the influence of the testis and others under the influence of the ovary. These characters would not be developed unless stimulated by the appropriate gonad. Other characters were evolved whose development was influenced by the gonads in a different way; they developed unless they were inhibited by a gonad—the gonad of the opposite sex to that to which they belonged.

It can easily be imagined that the circulation of one hormone in individuals of one sex and of another in the other sex would greatly simplify the evolution of new sexual characters. For normal growth depends on a delicate balance of circumstances: upset the balance ever so slightly, and a new type of growth may result. A new mutation may turn up, which would have precisely the same effect on all individuals if no hormones were concerned in sex determination. But it might easily upset the balance in one direction in individuals with one sex hormone, and in the other direction in individuals with another. If the sex difference thus produced were in any way advantageous, natural selection would tend to preserve it,

PARTIAL CASTRATION

Experiments in partial castration have been undertaken to find whether the sex characters are developed to a less extent if one testis or one testis and a half be removed, or if only a minute fragment of testis is left behind. The rather surprising result of these experiments is that a fragment only one-hundredth of the size of the two testes suffices for the complete development of the sexual characters. If, however, the amount of testicular substance be very slightly less than this minimum, the sexual characters do not develop at all. It is probable that intermediate amounts of testicular substance would produce intermediate effects, but this has not yet been shown. These points are expressed diagrammatically in Fig. 13.*

Since in normal cases the testes are enormously much larger than the minimum size required for the full development of the sexual characters, it follows that in normal cases the actual size to which the sex organs grow does not depend on the amount of testicular hormone. On what, then, does it depend?

The case is the same as that of the "horns" of the male stag-beetle (see page 43), though no hormone at all was concerned in that case. The larger the individual, the larger relatively the characters; so that rather large individuals have them very large, and rather small individuals have them very small. The antlers of deer, the finger pads of male frogs, various appendages of the heads

* This account applies to the Mammals. Conditions are rather different in birds.

of birds, these and innumerable other instances might be adduced which obey this rule.

*Normal amount
of testicular
substance*



*Amount required
for full development
of sex characters*

*Below this amount
sex characters do
not develop at all*



FIG. 13.—DIAGRAM ILLUSTRATING THE AMOUNT OF TESTICULAR SUBSTANCE REQUIRED FOR THE DEVELOPMENT OF MALE SEX CHARACTERS IN MAMMALS.

In the case of the more essential sexual organs, there is but little variation in size ; for natural selection has wiped out ill-adapted forms and preserved only the most efficient.

THE TRANSPLANTATION OF GONADS FROM ONE SEX TO THE OTHER

So far we have tacitly assumed that the testicular hormone is always different from the ovarian hormone, but we have not proved that such is the case. From what has gone before we might assume that the mammalian embryo is from the beginning either male or female and can never have organs of the opposite sex ; that no sex organs will develop unless the sex hormone is present ; and that it matters not at all whether the hormone happens to be produced by a testis or by an ovary. This would mean that the sex chromosomes were supreme in sex determination, but that they could only show their effect when the (single) sex hormone was present.

If this were true, it would follow that the rudimentary sex organs of a young castrated male would develop into normal male organs if an ovary were engrafted ; and similarly the rudimentary sex organs of a young ovariectomised female would develop into normal female organs under the influence of an engrafted testis.

To a very slight extent this may be true in frogs ;* but in mammals it has been shown to be quite untrue.

* A castrated male frog does not clasp the female. It has been stated that if a piece of ovary be grafted into the castrated male, the instinct to clasp is re-acquired. Further, the pad on the index finger is redeveloped to some extent. If this is true, some of the constituents of the ovarian hormone must be the same as some of the constituents of the testicular hormone in this case. The sex chromosome equipment of the parts concerned must play some part in the matter, for the ovarian hormone does not call forth the clasping instinct nor the finger pad in a female. But the experiment is in need of confirmation.

If an ovary be grafted into a castrated male rat or guinea-pig, he becomes "feminized" in a most remarkable way. In favourable cases the teats grow large and begin to secrete milk, and the instinct to suckle young is developed. The mating instinct also becomes female. On the other hand the male organs (copulatory organ, glands, etc.) are not stimulated to grow at all; indeed, it is possible (though not certain) that they grow even more slowly than in an ordinary castrate.

If a testis be grafted into an ovariectomized female, the converse takes place. The little tubercle which is the representative of the male's copulatory organ grows till it is nearly as large as the latter. The coat loses its feminine fineness and grows coarse like that of a male. The sexual instincts also become male. The female organs do not develop.

Clearly, the sex chromosomes do not prevail against the sex hormones in mammals. In the early embryo it is the sex chromosomes that decide whether the gonad is to be a testis or an ovary. If there is one sex chromosome it becomes a testis: if two, an ovary.* This testis or ovary does the rest, by secreting a hormone which causes the whole of the body to be male or female as the case may be. No matter that a given cell of the body has but one sex chromosome; that cell will develop in the female way if the testes are removed and ovaries grafted in their stead. All parts of the body are under the control of the gonads as far as the sex characters are concerned; but the gonads themselves are (in the embryo at least) under the control of the sex chromosomes.

* The reverse is the case in birds and moths. See p. 52.

In insects, as we have seen, not only the cells of the gonads, but all the cells of the body, are under the direct control of the sex chromosomes. Sex hormones are not produced, and castration, ovariectomy, and transplantation are without effect.

THE ORIGIN OF THE TESTICULAR HORMONE

The reader's curiosity will no doubt have prompted him to ask from what part of the testis the sex hormone is produced—whether it is produced by the germ cells themselves or by some special cells set aside for the purpose.

In the higher animals the testis consists of a number of minute coiled tubes, all of which are blind at one end but open at the other into a tube directly continuous with the vas deferens. Each little tube is lined by germ cells, which go through their various transformations and give rise to sperms. The latter, before they are quite fully formed, are attached in bunches to special nurse-cells, whose function it is to nourish them. The ripe sperms travel down the little tube until they arrive at the vas deferens, by rhythmic contractions of the walls of which they are ejected to the exterior during copulation. Each little tube has a firm coat of connective tissue cells, and between the tubes is a mass of rather large glandular cells called interstitial cells, containing secretions in the form of granules. The whole testis is surrounded by a thick sheet of connective tissue. A thin slice through a single tubule, together with outlines of the surrounding tubules and the interstitial cells between them, is shown in Fig. 14. In Fig. 15 a single nurse cell

with developing spermatozoa is shown at a higher magnification.

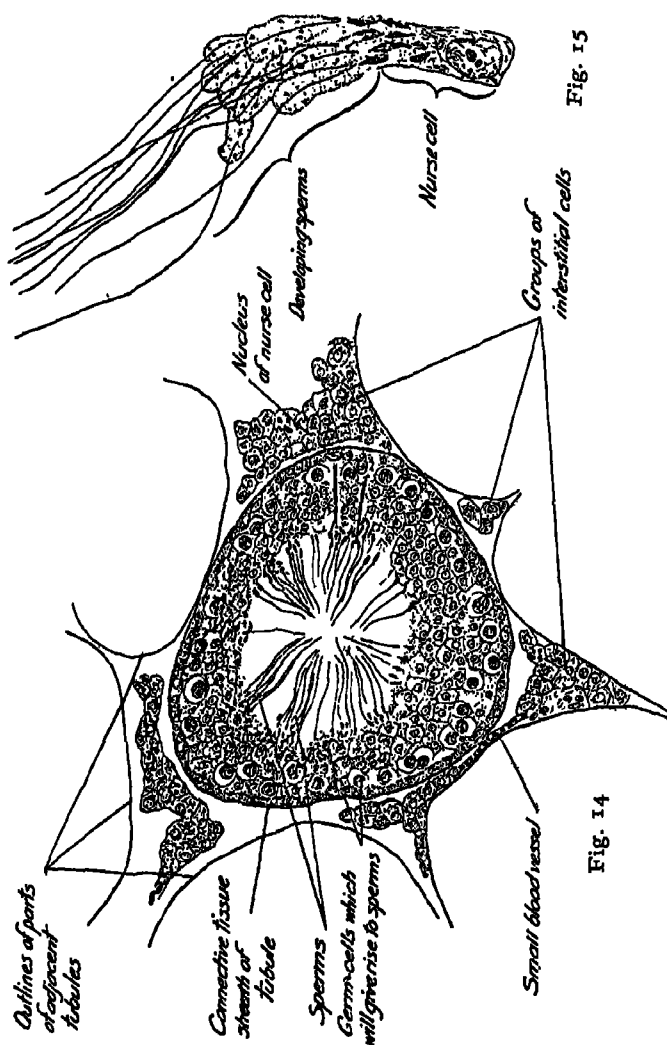


Fig. 15

Fig. 14

FIG. 14.—A THIN SLICE THROUGH A SMALL PART OF THE TESTIS OF A MOUSE. MAGNIFIED. A SINGLE TUBULE IS SHOWN IN DETAIL, TOGETHER WITH THE OUTLINES OF THE ADJACENT PARTS OF OTHER TUBULES AND THE INTERSTITIAL CELLS LYING BETWEEN THEM.

FIG. 15.—A NURSE-CELL, WITH DEVELOPING SPERMS ATTACHED TO IT.

Analysing the matter, we see that the hormone must be secreted either by the germ cells, or by the nurse cells, or by the interstitial cells, or by the connective cells. The

latter, however, may be ruled out, because they are obviously unable to secrete anything.

To ascertain which of the other three possibilities is the true one, let us examine a "retained" testis, that is, a testis which has remained within the abdomen instead of descending to the normal external position. Individuals in which the testes fail to descend have the various sexual characters, including the sex instinct, normally developed, so that evidently the retained testis produces its hormone all right. When we examine the retained testis in section we find that there are often *no germ cells at all*. Evidently it is not the germ cells which produce the hormone. Interstitial cells and nurse cells are present, and the examination of the section is not sufficient to decide which of these two sorts of cells is concerned.

This latter problem is answered by an examination of the testicles of certain "eunuchoid" individuals—that is, individuals from which the testicles have not been removed but in which, nevertheless, the sexual characters are not properly developed. Certain "eunuchoid" rabbits were found in which the little tubes of the testis were perfectly normally developed, with germ cells and nurse cells, *but with much less than the normal amount of interstitial tissue*. *The inference is that it is the interstitial cells and not the nurse cells which secrete the testicular hormone*. It is by no means impossible that the interstitial cells also supply nutriment to the developing germ cells.

In birds the evidence as to which part of the testis is concerned is inconclusive. In amphibia there is some evidence that it is the sperms themselves which produce the hormone. The evidence is that in the newt the male

characters are not developed till the sperms are produced in the winter, and again when in late spring the sperms disappear, the male characters disappear also.

A rival school of thought derives the hormone in the newt from certain cells which form the walls of the little compartments in the testes in which the sperms become mature. Every year a number of these cells enter the compartments and begin to devour the sperms. They become loaded with granules, which may be derived from the ingested sperms or which may be the substance which causes the assumption of the male characters. That these cells are the cells which secrete the sex hormone is rendered probable by the fact that radium destroys the germ cells, but it does not cause the male sex characters to disappear unless the glandular tissue is also destroyed; and again the glandular tissue, but nothing else in the testis, is destroyed by galvano-cauterization, and this operation is followed by complete disappearance of the glandular tissue.

In opposition to this theory, it has been recorded that certain newts have assumed the male sex characters *in the complete absence of glandular tissue*. The evidence is so conflicting that it is not yet possible to decide which element of the newt's testis produces the hormone.

Let us turn to the seat of production of the ovarian hormone, and for simplicity's sake let us confine ourselves to the mammals.

THE ORIGIN OF THE OVARIAN HORMONE

The ovary of a Mammal is a solid rounded body formed largely of spindle-shaped cells. There is a large

number of hollow spherical pockets scattered among these cells.

It is within these pockets, the walls of which are three-layered, that the eggs are found. There may be one or several eggs, attached to the inner wall of the pocket by rather irregular strands of tissue. (See Fig. 16.)

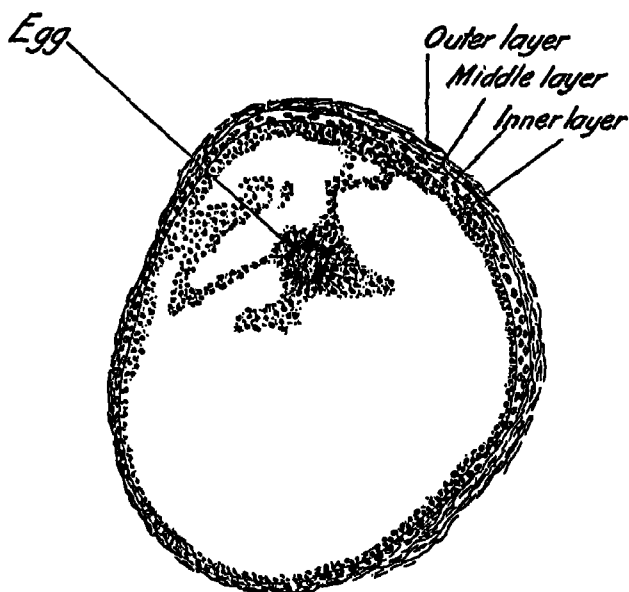


FIG. 16.—A THIN SLICE THROUGH ONE OF THE EGG-CONTAINING POCKETS IN THE OVARY OF A RABBIT. MAGNIFIED.

When the egg is ripe, the wall of the pocket breaks at one place and allows it to escape. Having escaped from the pocket the egg passes down a tube towards the womb and is fertilized by a sperm if insemination has taken place at the right time. Now a curious change takes place in the pocket from which the egg has escaped. The cells which compose the inner layer of the wall of the pocket, together sometimes with some of the cells composing the

middle layer, invade the cavity of the pocket, enlarge, increase in numbers, and eventually fill the cavity completely. The cells begin to secrete actively, and become yellow in colour. The whole mass of cells is called the "yellow body." Under the influence of the secretion of the yellow body the breasts swell and the womb undergoes enlargement and modification to meet the requirements of impending motherhood. The yellow body soon disappears unless the egg has been fertilised.

Now often a very similar thing takes place without the bursting of a pocket. The egg simply dies, and the pocket becomes filled with cells proliferated from the middle layer of the wall of the pocket. These cells either remain in spherical masses, or become separated and travel to all parts of the ovary so that one could not guess their origin. It appears that their function is similar to that of the yellow body: their secretion encourages the growth of female organs, such as the breasts and womb. It seems probable, though as yet it is not proved, that the development of the female reproductive organs from the embryonic to the mature condition is due to the cells of the inner and middle layers of the walls of the ovarian pockets. They may exert their effect before the pocket has undergone any changes; or after the egg has died and the pocket become invaded; or after the egg has burst out and the pocket become invaded. It is in the latter case that the effect is greatest and leads to the condition characteristic of pregnancy, because the yellow body thus formed is larger than the mass of cells formed after the death of an egg and secretes more actively.*

* If the liquid contained in the pocket is injected into an immature rabbit, sexual maturity is attained long before the normal time of puberty. It appears that the liquid has a considerable amount of the sexual hormone dissolved in it.

It should be noticed that the greater the amount of tissue comparable with the tissue of the yellow body, the greater the development of the female sexual organs. This is in marked contrast with the interstitial tissue of the testis, the amount of which (as we have seen) bears no relation to the state of development of the male sexual organs, unless that amount is a very short way above a very small minimum at which the sexual organs do not develop at all.

THE INFLUENCE OF THE ADRENAL AND PINEAL GLANDS ON SEX

Other ductless glands besides the gonads have an effect upon the development of the sexual characters. These glands appear quite similar in the two sexes, but if they are diseased the reproductive organs do not develop properly and the individual concerned may grow up with imperfect organs of both sexes. For instance, women with male characters such as a deep voice, beard, and peniform clitoris, are often found to have tumours of a ductless gland called the adrenal, situated near the kidney. Probably the effect of the tumour is to increase the amount of secretion by the adrenal. If so, the adrenals would appear to have a masculinizing effect. In this connection it is worth noticing that certain cells of the adrenals are similar to interstitial cells of the testis. Again, sexual precocity in boys—which may amount to puberty at the age of three years—is sometimes associated with tumours of the pineal, a small ductless gland connected by a narrow cord with the upper surface of the brain. It seems probable, though

not certain, that the effect of the pineal is to retard sexual development, and that the tumour destroys the pineal and thus prevents its retarding influence.

CONCLUSION

It is the sex chromosomes that decide the sex of animals as far as their gonads are concerned. In some of the lower animals (insects) the sex chromosomes also decide the sex of every cell of the body. In the higher animals the gonads take on the task of sex determination as far as the other sex characters are concerned. They achieve their effects by the secretion of hormones and also probably in some cases by removing substances from the blood. The testicular hormone stimulates the growth and differentiation of male organs and suppresses the female organs, while the ovary has the reverse effect. In mammals, the testicular hormone is probably secreted by the interstitial cells of the testis. The ovarian hormone is probably secreted by cells forming the walls of the pockets in which the eggs lie. When an egg is shed from the ovary, these cells increase in size and number so as to fill the pocket. In this condition they exert their maximum effect and (if an embryo is present) cause the womb and breasts to undergo the changes characteristic of pregnancy.

CHAPTER V

ABNORMALITIES OF SEX

INTRODUCTION

THE chromosome mechanism of sex determination, coupled as it is with hormone control in the higher animals, seems so beautifully adapted to the production of the two separate sexes that it is with something of a shock that one occasionally finds it going astray. In a species which is not normally hermaphrodite, an individual will sometimes appear which is intermediate to some extent between a male and a female. Such individuals are not very rare, and they occur in the most diverse groups of animals from the lower Crustacea up, alas, to man himself.

There is no single general cause underlying these abnormalities. They deserve study because they throw light on normal processes and because no theory of sex-determination would be complete which did not cover them. It is to be hoped that knowledge of abnormalities in the higher animals may throw light on how sexual abnormalities in man may be prevented and may be treated medically and legally. It will be my object in this chapter to bring abnormalities into line with the theories already outlined.

We will take first the case of the sexually abnormal cow, or "freemartin."

THE " FREEMARTIN "

Normally a cow produces only one calf at a time, but occasionally she produces two. If both these calves are males, or if both are females, all is well. But if one is a male and the other is a female, then the female, in about nine cases out of ten, is abnormal. It is called a "freemartin," and has many male characters. Generally it is a nearly or quite normal female externally, but when it is dissected the internal organs are found to be predominantly male. The womb is poorly developed, and where one expects to find the ovaries there is a pair of testes (not, however, containing sperms). The various ducts and glands connected with the male apparatus are fairly well-formed.

Quite recently the cause of this condition has been ascertained. An embryo calf within the uterus of its mother is surrounded by a sack of thin living tissue. This sack, the "chorion," is abundantly supplied with blood-vessels arising from the embryo. Now when there are two embryo calves within the same uterus, their chorions nearly always fuse together, and their blood-vessels join up so that blood flows directly from one embryo into the other. This mixture of blood does not affect either individual if both are of the same sex, but if the sexes are different there must be hormones making for one sex circulating in the blood of an individual of the other sex.

It might have been supposed that the effect of this would be that *both* individuals concerned would become intermediate as regards sex, but this is not the case. The reason

appears to be that the testis develops and begins to secrete its hormone sooner than the ovary. When fusion of chorions takes place the testis hormone is poured into the female, whereas but little ovarian hormone has been elaborated to pass in the opposite direction into the male. So the male is unaffected, whereas the various organs of the female are modified towards maleness. The ovaries themselves are transformed into testes, so that from that time forward no ovarian hormone at all is produced.

"Freemartins" are invariably sterile. Their testes are never sufficiently normal to produce sperms, and anyhow there is no penis, the external organs (as mentioned before) being almost typically female.

SEX-INTERGRADE PIGS

Individuals presenting both male and female characters are not very rare among pigs and goats. Farmers call pigs of this sort "wildews." In the New Hebrides, a group of islands in the western Pacific Ocean, such pigs are quite common. On some islands there are one or two of them in every little native village. To the natives they are of peculiar value, not only in the purchase of brides, but also in the carrying out of their various religious ceremonies. At initiation into the Tamaté society, it devolves upon each neophyte to slap the "rawé" or sex-intergrade pig.

The "wildew," the "rawé," and the sex-intergrade goat resemble the "freemartin" so closely in the anatomy of their

reproductive organs that it might have been supposed that the underlying cause was the same. But there are several reasons why this view cannot be upheld. In the first place, fusion of chorions has never been found in the pig. Secondly, sex-intergrade goats have been born singly, which precludes hormone influence from a twin embryo. Lastly, it has been shown that certain boars continually sire sex-intergrade offspring, a fact which cannot be brought into line with the idea that these peculiar animals are comparable with "freemartins."

A theory which has been propounded to cover these cases is that they are really males, in which the testis started to secrete its hormone too late to stimulate the male primordia to perfect maleness or completely to suppress the female primordia. The result is that both sets of organs continue to grow, but only to a limited extent. The idea is that there is a definite time early in development when the sexual organs must be either encouraged or suppressed by hormones. If this time is passed by without hormone-control, no amount of hormones later on will suppress an organ completely nor will it suffice to bring about perfect development.

The theory, though probably partially true, will not account for the fact that sometimes the uterus of a sex-intergrade is as well-developed as in a normal female. It seems a plausible view that all sex-intergrades were true hermaphrodites in early stages of development—that is, that both testis tissue and ovarian tissue were present, and that early development took place under the influence of both hormones, sometimes one, sometimes the other preponderating. This view is borne out by the fact that

in adult sex-intergrade pigs it is not very rare to find both testicular and ovarian tissue. (See Fig. 17.)

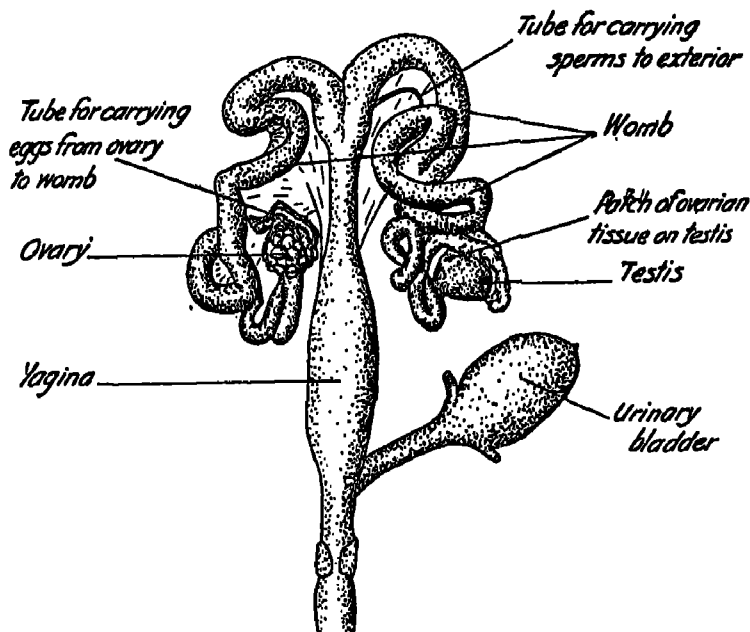


FIG. 17.—THE INTERNAL REPRODUCTIVE ORGANS OF A SEX-INTERGRADE PIG WITH BOTH TESTIS AND OVARY. REDUCED. THE EXTERNAL ORGANS APPROXIMATED TO THOSE OF A NORMAL FEMALE.

It is very rare indeed to find fully developed sperms in an intergrade, and (as in the "freemartin") the lack of a penis prevents the possibility of its acting as a male parent ; but it is not inconceivable that a specimen such as that figured might act as a female parent and bear offspring, though no case has been recorded.

The fact that a tendency towards the sex-intergrade condition is transmitted by the father and probably also by the mother, indicates that the chromosomes are concerned.

HUMAN SEX-INTERGRADES

At this point it may be well to mention what little is known about sexual abnormality in man. The chief difficulty in the study of this phenomenon is that external observation must in most cases suffice. Medical men have elaborated a remarkable classification which involves the use of names such as "*hermaphroditismus internus masculinus*" and "*pseudo-hermaphroditismus externus femininus*." These names are not of much value, but do not do any real harm unless the reader makes the mistake of supposing that "*masculus*" necessarily indicates an originally male, or "*femininus*" an originally female individual.

Inasmuch as these abnormal individuals are usually born singly and are similar in their anatomy to the intergrades in pigs and goats, it is reasonable to conclude that they are of similar origin. A fact pointing in this direction is that a tendency to sexual abnormality is certainly inherited in mankind.

It is generally practically impossible to say to which sex an abnormal individual should be legally assigned. It may be taken for granted, however, that whatever his or her true (chromosomal) sex may be, the sexual instinct will usually be male if testis tissue alone is present, and usually female if there is only ovarian tissue; while if both types of tissue are present, the instincts will either be indefinite or else they will oscillate from one to the other sex, as is the case in rats in which both testicular and ovarian tissue have been grafted.

However this may be, the important point is to prevent

the birth of sexually abnormally individuals ; and all who are not steeped in bigotry will admit that married people who have produced an abnormal individual or who have abnormal relatives should be strongly encouraged to practise contraception.

In addition to individuals who are markedly abnormal in their reproductive organs, there exist men of rather feminine stature and mentality and women of masculine type. While it is to be admitted that neither the hyper-masculine type of man (depicted so consistently by a well-known novelist) nor the hyper-feminine type of woman is a highly desirable member of society, the reverse cases, namely the effeminate man and manly woman, are still less ideal. Unfortunately little is known about the causation of this abnormality, and much has been ascribed to environment in the case of reversed sexual instincts ; but the latter are so often associated with stature inclining towards that of the opposite sex that the upbringing cannot be the whole root of the trouble. If the abnormality is a minor form of intersexuality comparable to the type of intersexuality which occurs in pigs and goats, it is probably inherited. If so, it will tend to disappear when public opinion is sufficiently educated to appraise the sexually abnormal at their actual values—when, for instance, men are so little attracted by the masculine woman that she remains unmarried.*

* The whole of this problem is complicated by the fact that we do not yet know what is really a normal male mentality nor what is really a normal female mentality. The greater part of one's ideas on this subject necessarily arise from early observation of men and women whose own mentalities in their turn were moulded by early impressions of their elders. It is possible that our ideals of male and female mentality are wholly artificial. The problem is discussed at greater length in Chapter X.

SEXUAL ABNORMALITIES IN BIRDS

Let us turn now from mammals to birds, in which group we shall find some of the most entertaining cases of sexual abnormality.

Not very rarely the ovary of a hen becomes diseased and disappears, or it may disappear as a result of old age. From what we have seen before, the ovary suppresses the male plumage and spurs ; so in these cases the spurs and long curved tail feathers of the cock appear. The comb, however, requires testicular tissue for its normal male development, and ovarian tissue for normal female development ; it therefore shrinks somewhat when the ovary is diseased. Fig. 18 is a photo of an individual of this type in my possession.

In a few of these cases a most interesting event now occurs. The decaying ovary becomes invaded by cords of cells which grow and form a testis. In one authenticated instance this testis became normal and functional, and not only did the bird develop a comb, but it mated as a cock with an ordinary hen and became the father of chickens ! This bird had laid fertile eggs before its ovary became diseased. The same individual was a mother first, a father afterwards.

Another similar case has been reported in the pigeon. Here the ovary was attacked by tuberculosis, and the author of the paper concerned with the case ascribes the change of sex to the fact that tuberculosis increases the rate of metabolism, and increased rate of metabolism tends towards maleness, especially when the ovary is destroyed.

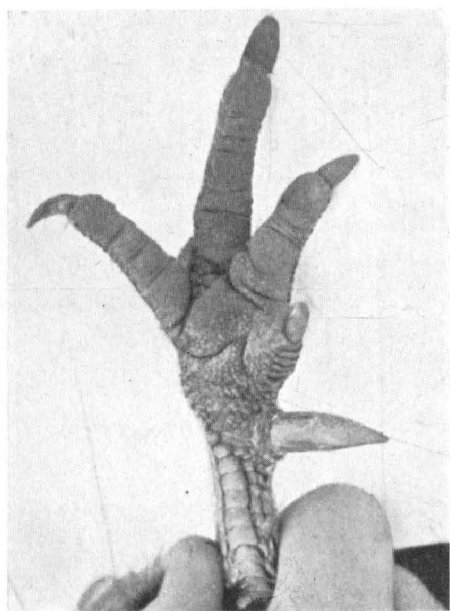
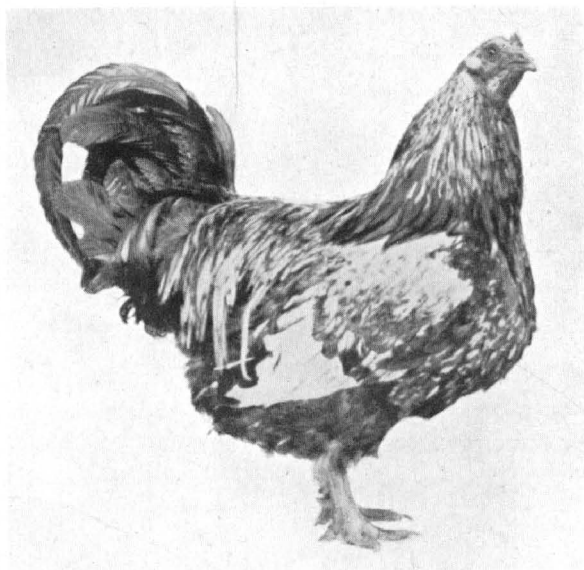


FIG. 18. A sexually abnormal fowl, with male plumage and spurs, but female carriage and a very small comb. The spur is well shown in the lower photograph.

(Photo by Mr. D. Kempson)

SEXUAL ABNORMALITIES IN INSECTS

We will now take the case of insects, where matters are less difficult because no hormone secreted by the gonad is concerned. It will be remembered that it is here the chromosomes alone that decide the sex.

No insect is normally hermaphrodite, but individuals are sometimes found which are male in some parts of their body and female in other parts. It is as though one has taken an imaginary knife and divided the insect, and all parts (both external and internal) on one side of the path of the knife had become male and all parts on the other side female. Sometimes the right side of the animal is of one sex, the left side of the other sex, in which case the individual has a testis on one side and an ovary on the other; sometimes the anterior end is of one sex and the posterior end of the reverse; sometimes the line of demarcation is less simple. These curious individuals are called "gynandromorphs," and they occur in bees, flies, butterflies, moths and other insects.

The fact that hormones are not involved makes it probable that the male parts of the body are male in their chromosomes, and the female parts female in theirs.* How does this state of affairs come about? The most plausible suggestion, as far as insects other than bees are concerned, is that the individuals are female to begin with; that is, that there are two sex chromosomes in the egg. At the first cell-division, one of these sex chromosomes

* This is known to be the case in the fruit-fly, from the condition of the sex-linked characters on the two sides of the body.

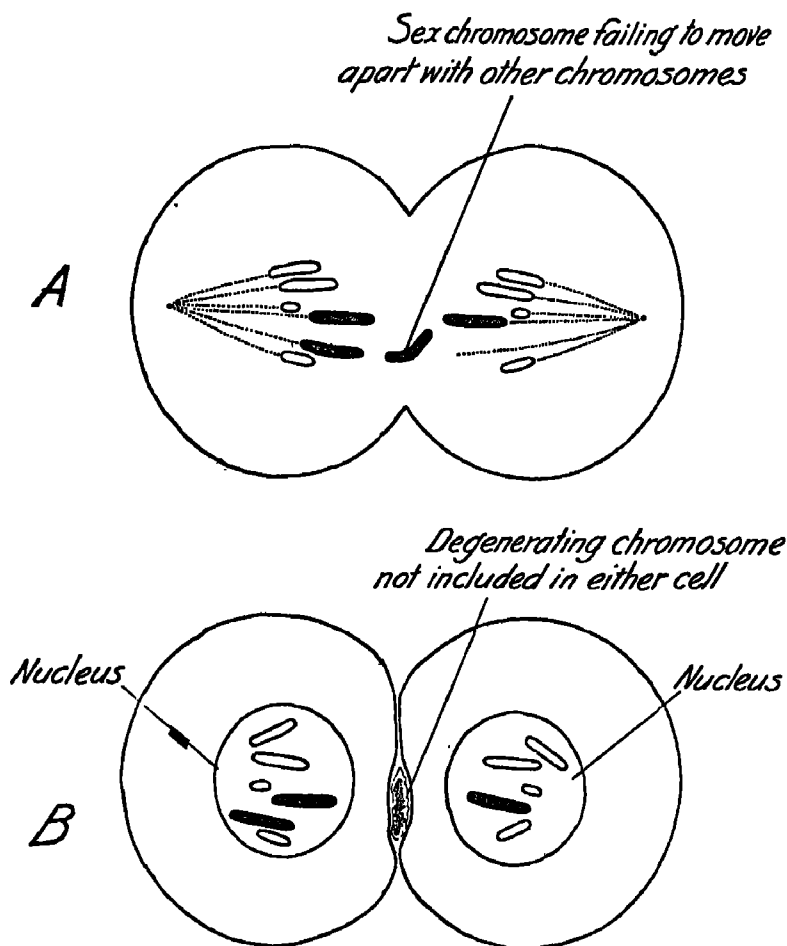


FIG. 19.—DIAGRAM ILLUSTRATING AN HYPOTHESIS TO ACCOUNT FOR GYNANDROMORPHISM.

- A.—The egg dividing into two cells. The division is abnormal in that one of the sex chromosomes fails to move apart with the other chromosomes.
- B.—The egg has divided into two cells. The left-hand cell (which will give rise to all the cells of the left side of the body) has two sex chromosomes, and is therefore female in constitution. The sex chromosome which failed to move apart is not included in either cell. The right hand cell (which will give rise to all the cells of the right side of the body) has therefore only one sex chromosome and is male in constitution.

divides normally, and one product of division passes to each daughter cell ; whereas when the other sex chromosome divides, one product of division passes to one daughter cell while the other fails to move and is included in neither daughter cell, but is left out altogether and decays. (Fig. 19.)

The result is that one of the two daughter cells has one sex chromosome, and all its descendants will be male ; whereas the other has two, and all its descendants will be female.

In bees a simpler hypothesis accounts for the facts. We shall see in Chapter VII that in bees sex is determined in a peculiar way. One set of chromosomes makes for maleness, two sets for femaleness. The hypothesis to account for gynandromorphs in bees is that the egg while being passed down the egg-tube sometimes divides prematurely into two, and one of these two cells may be fertilized by a sperm while the other remains unfertilized. One cell would then have a double set of chromosomes and its descendants would be female, whereas the other cell would have only a single set and would be male.

Leaving gynandromorphism, we now tackle an interesting but rather more difficult case. It is found that when different races of insects are crossed together, intersexual individuals may be produced.

The gypsy-moth furnishes the best example. The male has dark wings and his antennæ are comb-like, whereas the female has pale wings and her antennæ are simple.

If males of a race from Gifu, in Japan, are crossed with females from Kumamoto, all the females produced are

intersexual. Their wings are darker than normal, and their antennæ are slightly comb-like.

Other crosses give more marked intersexuality. The wings are darker and the antennæ more pectinate, and the external reproductive organs are masculinized; but eggs are still produced and the sex instincts remain female.

Other crosses again give still more marked intersexuality, with undeveloped ovaries and intermediate instincts; yet others give stages still more masculine, with the gonads to some extent transformed into testes and with male instincts. Finally, when male gipsy-moths from Ogi, in Japan, are crossed with others from Fiume, all the females produced are completely transformed into males.

In moths, the male has two sex chromosomes, while the female has one.* The facts of intersexuality in the gipsy moth are accounted for on the suppositions that in moths the sex chromosomes make for maleness; that every egg contains a certain amount of something making for femaleness; and that in different races of gipsy moths the amount or the "potency" of the sex chromosomes and of the "something" in the eggs varies.

It is supposed that the feminizing factor present in every egg is able normally to over-ride the masculinizing influence of a single sex chromosome, so that an individual with only one sex chromosome is a female; whereas if two sex chromosomes are present, they override the feminizing factor and produce a male.

It is supposed further that in some races of gipsy moths the potency of the sex chromosomes and of the feminizing

* In this respect moths and birds differ from all other animals so far investigated. In all other animals it is the female that has two sex chromosomes.

factor are great ; whereas in other races the potency is small, and in others again the potency is of various intermediate grades. The mechanism works perfectly well in each race whatever the potency may be, since in any one race one sex chromosome is always weaker and two sex chromosomes are always stronger than the feminizing factor.

But if a male gipsy moth of a race in which the potency is high be mated with a female of a race in which the potency is low, abnormalities ensue ; *a single very potent sex chromosome is able to override more or less completely a feminizing factor of low potency*, and thus individuals which should have been females are more or less completely changed into males.

Examination of these intersexes reveals a most interesting point. A slightly masculinized female does not differ from a normal female in any sexual characters at random, *but in the sexual characters which are the last to appear in the course of development*, namely the colour of the wings and the pectination of the antennæ. A rather more masculinized female resembles a male not only in the colour of the wings and pectination of the antennæ but also in a character which develops rather earlier, the external reproductive organs. Further masculinization results in the male development of the gonads themselves, the earliest sexual organs to be differentiated (as well as of the external reproductive organs and the antennæ and colour).

These facts signify that a masculinized intersex starts life as a female, and its reproductive organs develop in the female way up to a certain time. This time is early in highly masculinized intersexes and late in slightly mascu-

linized ones. After that time the organs develop in the male way. It has been suggested that two substances are produced which circulate in the blood, one making for maleness and the other for femaleness. In a normal female the former predominates until after development is complete; but in masculinized intersexes the male-producing substance is produced in greater quantity than the feminizing substance sooner or later during the course of development. From that time forward development is male.

Our last cases of sexual abnormality occur in the fruit-fly, *Drosophila*. There is a strain of this fly which is peculiar in that all the chromosomes are present in triplets instead of in pairs. Intersexes are continually being produced by this strain. When their chromosomes are examined, it is found that there are only two sex chromosomes, while the other chromosomes are in triplets. We need not discuss how this state of affairs has come about: the important thing for us is to note its implications. It implies that whereas the sex chromosomes here make for femaleness, *the other chromosomes make for maleness*; and when they are present in more than their usual numbers they partly outweigh the two sex chromosomes and thus an intersex is produced. The important conclusion is reached that it is not the sex chromosomes alone that determine sex, but the sex chromosomes in relation with the other chromosomes.

The matter is complicated; but it is of such interest in showing that an apparently simple matter is not simple at all, that I shall push the analysis still further. It would be interesting to know whether all the chromosomes other

than the sex chromosomes exert the same amount of masculinizing influence. Nature provides the answer in the shape of certain intersexes which are more female than the usual intersexes. When their chromosomes are examined, it is found that they are the same as those of the usual intersexes except in one point : namely, that there is one less chromosome. There are the two sex chromosomes, and three of each size of ordinary chromosome *except* the smallest size. *Of the smallest size there are only two.* Since the absence of one of these little chromosomes makes for a noticeably more female type of intersex than usual, it is evident that the little chromosomes exert more masculinizing influence than their size would lead one to expect.

CONCLUSION

The reader will probably admit that our examination of nature's failures only serves to emphasize the delicacy of the balance of factors which results in normal development. The freemartin teaches us how early in life the hormones come into play ; the rawe puzzles us, and confronts us with problems of inheritance ; the cock that was a hen surprises us with the completeness of its sex reversal, and proves the latent potentiality of one sex to develop into the other. The gynandromorph insect shows what happens when a sex chromosome is not quite accurate in its manoeuvres at cell division ; the gipsy moth tells us how the different geographical races of a species may differ from one another in the most unexpected way, and may produce monstrosities when bred together ; and finally *Drosophila*

insists that matters of sex determination are not quite so simple as other animals would have us believe, even when sex hormones are not concerned.

Let us take leave of our instructive but often repulsive acquaintances, and turn along one of the most fascinating by-paths in the whole domain of sex-biology.

CHAPTER VI

HERMAPHRODITISM

INTRODUCTION

HERMAPHRODITISM may be defined as the production of both sperms and eggs by one and the same individual. This chapter deals only with those animals that are *normally* hermaphrodite. A discussion of the hermaphrodite monstrosities that are occasionally found in species in which the sexes are normally separate was given in the last chapter.

Fig. 20 is intended to show in a diagrammatic way which animals are hermaphrodite and which are not. Blackness indicates that the sexes are separate: spots represent hermaphroditism. Only the outside edge of the diagram represents ascertained fact. The relationships of the groups to one another as shown by the ramifications of the ancestral tree are hypothetical, but based, of course, on a minute comparison of their structure and development. The spotting and blacking-in of the ramifications of the tree (except the outside edge of each branch) gives my idea as to whether the ancestral animals were bisexual or hermaphrodite. The reader should not trouble to look closely at the smaller groups of animals, unless he happens to be already acquainted with them; but he should *confine himself to the larger groups and to the names which*

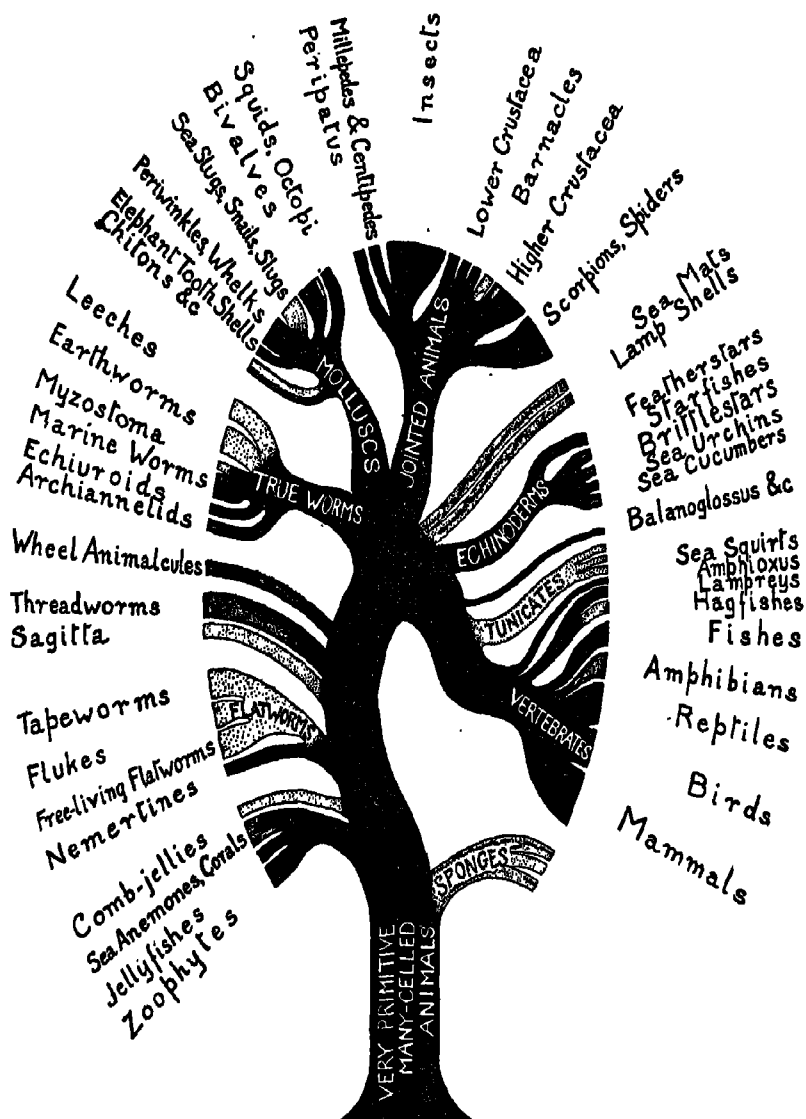


FIG. 20.—DIAGRAM ILLUSTRATING THE OCCURRENCE OF HERMAPHRODITISM. BLACKNESS INDICATES THAT THE SEXES ARE SEPARATE: SPOTS INDICATE HERMAPHRODITISM. FOR FURTHER EXPLANATION SEE TEXT.

are familiar to him, and should check the following statements by reference to the diagram.

The great majority of animals have separate sexes, but among groups which are essentially bisexual one finds single hermaphrodite species, or small groups of hermaphrodite species. The chief groups of hermaphrodite animals are the flatworms (liver-flukes, tapeworms, etc.), the earthworms and leeches, the higher univalve molluscs (such as sea-slugs, land-snails and land-slugs), barnacles and their allies, and the tunicates (a varied group related to the vertebrates, including the sea-squirts, which are familiar objects attached to rocks on the shore near low-tide mark). Several of these groups have single species and small groups of species among them in which the sexes are separate.

IS HERMAPHRODITISM PRIMITIVE OR SECONDARY ?

The main question is whether hermaphroditism is to be regarded as a primitive character, which is retained by some groups of animals and is lost by others ; or whether it is a secondary character acquired for some particular reason by certain groups. It is evident, and allowed by all, that single hermaphrodite species in, *e.g.*, the echinoderms, are derived from forms which were not hermaphrodite, but with regard to the large hermaphrodite groups mentioned above the point has been argued at length. Inasmuch, however, as the more primitive groups of segmented worms (Annelida) are (with certain exceptions) bisexual, while it is the more elaborate and specialized groups which are hermaphrodite, it seems allowable to

argue that here at any rate hermaphroditism is secondary. The same thing applies to the molluscs; it is the more specialized group of univalves that is hermaphrodite. Here there seems no doubt that hermaphroditism is secondary, for the tubes which lead the sperms to the exterior do not correspond with the tubes which subserve the same function in the primitive univalves, but are new structures plastered on, as it were, to individuals which are really females but which have become hermaphrodite.

The case of the flatworms is much more obscure, because the primitive members of the group as well as the specialized ones are hermaphrodite.

One might conclude that they are derived from forms which were never anything but hermaphrodite—that their ancestors were always hermaphrodite. This would involve the supposition that the separation of the sexes arose independently in the ancestors of the zoophytes and jellyfish on the one hand, and in the higher groups, such as true worms, Molluscs, jointed animals, and Vertebrates on the other. This would be represented in the diagram by spotting the whole of the main stem of the ancestral tree up to the level where the flatworms branch off. This is not wholly unlikely, but I incline to the view that the common ancestors of all the great groups of animals had separate sexes and that hermaphroditism has here and there sprung up by the dropping out of one sex and the modification of the other sex to the hermaphrodite condition. This view is indicated in the diagram by the blacking-in of the ancestral tree down to below the bases even of the lowest branches.

It is doubtful whether the extreme base of the tree,

representing the very earliest many-celled animals, should be black or spotted ; for certain species of colonial single-celled animals are bisexual, while in other species each colony produces both small active gametes and larger passive ones. The usual opinion, which is adopted in the diagram, is that it was from colonies of the former type that many-celled animals arose, *i.e.*, that many-celled animals were from the first bisexual.

THE SIGNIFICANCE OF HERMAPHRODITISM

The next question is : " Why did some groups of animals give up the separation of the sexes and take to hermaphroditism ? " To answer this question, we must first try to see whether the hermaphrodite groups have anything in common. In general we may say that they are slow-moving (earthworms, snails and slugs), sedentary (sea-squirrels), or parasitic (flukes and tape-worms). From these facts it has been argued that hermaphroditism has evolved where, by reason of slow movement, fixed habit of life, or parasitism, regular cross fertilization has become difficult, and where a means of self-fertilization would be advantageous by ensuring that individuals which did not chance to meet others of the same species could reproduce their kind. It appears that this is quite a plausible suggestion as regards flukes and tapeworms, for it must often come about that only one individual inhabits the body of a specimen of the species on which it is parasitic, and in this case it could only reproduce by parthenogenesis or by self-fertilization ; and for the latter hermaphroditism is,

of course, necessary. But this will not account for hermaphroditism in earthworms and snails and slugs, for in these groups self-fertilization never, or hardly ever, takes place. It is possible, however, that such slowly-moving forms derive this advantage from hermaphroditism, that when two individuals meet fertilization can always take place (for there is no question of a male meeting a male nor of a female meeting a female), and further, each can fertilize the other at each meeting of two individuals. This is what probably happens with earthworms and snails.

Another theory to account for the fact that it is slow-moving, sedentary, and parasitic forms that tend to be hermaphrodite, is that the slow metabolism characteristic of such forms makes them suitable for the simultaneous production of both male and female sexual cells. Sperm-production and egg-production are supposed to be such diametrically opposite functions that both could not be performed in an active animal, whose metabolism must be subjected to as few and as simple strains as possible. This theory is difficult to test experimentally and we may dismiss it with the observation that there might be an element of truth in it. A similar theory derives hermaphroditism from the feminizing influence of a sluggish form of existence acting on the male sex, accompanied by the disappearance of the female.

Before turning to other aspects of the problems of hermaphroditism, we might with advantage notice the single fluke which, cutting adrift from the tradition of all its relations, has given up hermaphroditism and taken to the separation of the sexes. It has evidently not found this congenial, for the male and female individuals go about

together, the female held in a groove on the under side of the male's body. The object of this perpetual proximity is probably to insure that when once a male individual has met a female, there may never again be a chance of the sperms of the one or of the eggs of the other being unused. A still more remarkable instance of a similar state of affairs is afforded by another fluke, *Diplozoon*. *Diplozoon* is hermaphrodite, but not self-fertilizing. In order to ensure fertilization, two individuals come together, and, as in the case just quoted, stay together. But they go even further, for they fuse together till literally they are of one flesh, and divorce is impossible. The male tube of each fuses with the female tube of the other, and perpetual copulation is thus achieved.

THE ORIGIN OF HERMAPHRODITISM

If hermaphrodite groups have been derived from ancestors which had separate sexes, this must have come about in one of three ways. Either (1) the male sex has dropped out, the female sex having become hermaphrodite ; or (2) both sexes have become hermaphrodite ; or (3) the female sex has dropped out, the male sex having become hermaphrodite. The second possibility would probably involve there being two recognizably distinct types of individual, both hermaphrodite, but one showing traces of the fact that it is a modified female sex, and the other that it is a modified male sex. Now hermaphrodite animals do not consist of two types of individual both hermaphrodite.* So we must conclude that one sex

* There is one exception to this rule, namely *Myzostoma cirriferum*, an animal allied to the true worms,

or the other has dropped out, and there is no reason to doubt that it is sometimes one sex and sometimes the other that has done so. In the case of the snails and slugs it is probably the male sex which has dropped out, for a reason which has already been mentioned (p. 104).

A series of barnacles gives a clear indication of how the male sex has gradually dropped out in the majority of these animals. The case is particularly interesting in that it was worked out by Darwin. Some of the more primitive species of barnacles have separate sexes, the males and females being of equal size and living independently. Other species are found in which the female sex is normal, but the males are minute and live attached to the female, on whom they rely for nourishment. The next step finds expression in certain species in which the large individuals have taken to hermaphroditism, but the little males still occur. Finally, in many species, hermaphrodites only are found, the male sex having completely dropped out.

It should be mentioned, however, that one distinguished author has expressed the opinion that the hermaphrodite barnacles are really males. Where two types of individual constitute the species, *i.e.*, when there are large hermaphrodites and small males—he still considers that only one sex is concerned and that that sex is the male; he holds that the female sex has completely dropped out. He supposes that every young barnacle has the potentiality both of growing to a minute male and of growing into a large hermaphrodite. It adopts the former course if it comes into contact with a fully grown individual, whereas it adopts the latter if it fails to do so. This theory is based on the fact that male Crustacea of various species tend

occasionally to have eggs as well as sperms in their testes, while the reverse is never the case ; and on the fact that when a male crab is parasitised by a certain animal it often takes on many female characters while a parasitised female crab does not take on male characters. In other words, the male sex seems in the Crustacea to take on female characters more readily than the female sex takes on male characters. But what the individual does in the course of development throws little light on what the species has done in the course of evolution.

In the case of one of the very few species of threadworms which exhibit hermaphroditism, there is a sexual generation living in fresh water. The male and female pair, and the eggs thus produced all turn into embryos which perish unless swallowed by a frog. If they chance to be swallowed they pass to the lungs and all grow into hermaphrodites. The eggs of the latter grow into embryos which pass from the frog to grow into the free-living males and females. The cycle then starts again. It will be observed that a bisexual generation alternates with an hermaphrodite generation. Here the hermaphrodites resemble females not only in general structure but also in their sex chromosomes, so that there is no doubt as to the course which evolution has taken.

ANIMALS WHICH CHANGE THEIR SEX

Hermaphroditism does not necessarily consist in the co-existence of sperms and eggs in the same individual at the same time. It happens not uncommonly that the

sperms are produced first, the animal being, to all intents and purposes, a male when it is young, and that subsequently sperms are no longer produced, but eggs appear instead. The animal is then usually female for the rest of its life, though in some cases it changes sex several times. Very much more rarely an animal is female first and male afterwards. It is difficult to say whether this arrangement is an adaptation to prevent self-fertilization, comparable to the various stratagems which plants often employ to this end, or whether it results from the fact that the type of metabolism required for the production of sperms is totally different from that required for the production of eggs. It might be that this type of hermaphroditism is a method of obtaining that division of labour which is usually obtained by the separation of the sexes. The individual starts life as a thorough-going male and ends it as a thorough-going female, and thus suffers none of the disadvantages of a compromise at any stage of existence, except just while the change is being made. But it must be realized that when hermaphroditism is of this type, the animal does not obtain the advantages of mutual fertilization nor of certainty of fertilization by any individual, which, as we have seen, accrue from the possession of both sperms and eggs at the same time.

The most interesting case of hermaphroditism of this sort is furnished by the Slipper Limpet, *Crepidula*, a univalve Mollusc which does serious damage to oyster beds. Young individuals attach themselves to the shells of old individuals, and while so attached they pass through the male stage of their career and fertilize the older individual, which has arrived at the female stage.

As the young individual grows older, it becomes hermaphrodite, and then its male organs disappear, and for the rest of its life it is a female. Meanwhile another individual attaches itself to it, and goes through the same changes. This process is repeated again and again until a chain of individuals is formed. Such a chain is shown in Fig. 21.

It is found that if a young individual does not become attached to a larger individual, it grows up much more rapidly. It seems not to have time to pass through a male stage, for it grows directly into a female. Thus the older individuals seem to exert a retarding influence on the young individual. The exact nature of the retarding influence is unknown, but it must be of a chemical nature, for it can be transmitted through water to a young individual which is not in actual contact.

CONCLUSION

The most primitive many-celled animals, which evolved from colonies of single-celled animals, were probably bisexual. As the various groups branched off from the ancestral stock, some (*e.g.*, the flatworms) become hermaphrodite at once, so that all their representatives to-day are hermaphrodite except a few which have gone back to separate sexes; but most of the large groups remained bisexual, some of their sub-groups subsequently becoming hermaphrodite. It is chiefly in sluggish, sedentary, and parasitic groups that hermaphroditism has appeared. The advantage of the ability to self-fertilize is probably a reason for the assumption of hermaphroditism by parasitic forms.

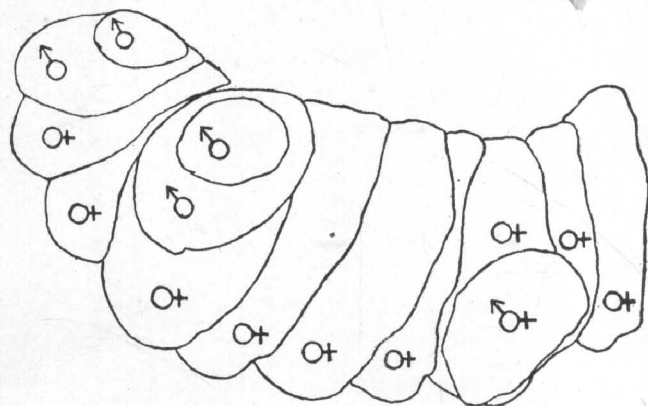


FIG. 21. A chain of individuals of the slipper-limpet, *rodite* ♂ male. ♀ indicates female. ♂ hermaph-
 The chain was collected and the sexes determined by Dr. J. H. Orton (*Photo by the*
Rev. R. A. Ellis).

Slow-moving forms may gain an advantage in the possibility of reciprocal fertilization. Perhaps hermaphroditism is not an adaptation to anything, but the direct effect of a sluggish mode of life on metabolism. Sometimes the male sex, sometimes the female sex, has dropped out, the other becoming hermaphrodite; it appears that in the case of the barnacles it is the male sex that has dropped out. Some animals are of one sex when young and of the other when old.

CHAPTER VII

PARTHENOGENESIS

INTRODUCTION

THE development of an unfertilized egg is called parthenogenesis, and the female which produces such an egg is called a parthenogénetic female. Since parthenogenesis is not sexual reproduction at all, it might seem paradoxical that an account of it should be included in this book ; but as a periodical alternative to sexual reproduction and as a method of sex determination it cannot properly be overlooked. Parthenogenesis as we see it to-day is a method of reproduction derived from sexual reproduction, and not a primitive method at all.

PARTHENOGENESIS AS AN END IN ITSELF

Parthenogenesis occurs sporadically in many groups of animals and is of very general occurrence in a few, namely, the wheel-animalcules, the " water-fleas " (which are lowly Crustacea), the plant-lice, and the bees and their relatives. In the bees it serves as a method of sex-determination, as will be explained later. In the other groups it seems to be an end in itself, an adaptation to special modes of life. Both the wheel-animalcules and the water-fleas live in pools

which are liable to dry up in the summer, and their eggs are dispersed by wind or by attachment to the feet of birds. It may readily be imagined that under these circumstances a pool may often be tenanted by only one individual. Without the ability to reproduce parthenogenetically, that individual would necessarily die without producing offspring.* A parthenogenetic individual on the other hand soon populates the pool and ensures the survival of the race. The same applies to plant-lice, though here it is a tree instead of a pool that has to be populated. Another advantage of parthenogenetic reproduction is that, males being unnecessary, every individual is a female, and therefore an egg-producer—a great advantage for rapid multiplication.

In all three groups male and sexual females appear at intervals—most abundantly in the autumn—and mating together they produce eggs which are resistant and often remain dormant over the winter. With the advent of spring they hatch, producing females which start the cycle again by beginning to reproduce parthenogenetically. A new succession of generations of parthenogenetic females follows.

It is almost certain that in a few species the succession of parthenogenetic females is never-ending—that the male sex has completely dropped out and that sexual reproduction no longer exists. It is proverbially difficult to prove a negative, but we know nothing to render the idea of everlasting parthenogenesis inconceivable.

The fact that males are most abundant at periods of unfavourable conditions—at the onset of winter—has given

* Unless it were a self-fertilizing hermaphrodite: see last chapter.

rise to the idea that external conditions completely govern the production of males. It can be shown, however, that external conditions are not the only factors at work. For if wheel-animalcules be kept artificially under unvarying conditions of temperature, abundance of food, etc., there is, nevertheless, a cycle of parthenogenic females followed by the production of males and sexual females, and then parthenogenetic females again, and so on. The cycle takes a month to complete. It is evident that there is an inherited rhythm of male-production independent of changes in the environment.* In the same way, plant-lice have an inherited rhythm of male production. The tendency to produce males grows with the number of generations. The female hatched from a winter egg produces no males at all or only produces a male with her last egg or two; her daughters produce males from their last few eggs; their daughters produce males from earlier eggs; and so on through a large number of generations until finally females produce males from their very first eggs.

But although there exists this inherited rhythm of male-production, quite apart from any changes in the environment, nevertheless changes in the environment have considerable effects in hurrying on the production of males or of retarding their appearance. Low temperature and starvation generally encourage the production of males, whereas high temperature and abundance of food retard it. This accounts for the fact that males are most abundant in late autumn. It is curious that these circumstances

* It should be pointed out, however, that the environment is perhaps not quite constant, for variation in the number of individuals must cause differences in the amount of oxygen and waste products.

have been distorted to support a theory that temperature and nutrition affect the determination of sex. They do not; all they do is to modify an inborn tendency of alternation between parthenogenetic and sexual reproduction. Coldness and starvation merely hurry on the change from parthenogenetic to sexual reproduction. They do not encourage the production of males only; they also occasion the production of special sexual females whose eggs require fertilization. The same conditions which help to produce males help also to produce precisely the opposite—namely sexual females—in the same abundance.

In the first chapter I stated that the number of chromosomes in the egg is half that in every other cell in the body, and I explained how the sperm, which carries the same number of chromosomes as the egg, makes up the full number characteristic of the species when it fuses with the egg in fertilization. A problem immediately presents itself: how is the number made good in parthenogenetic reproduction, in which no sperm is concerned? The answer is simple. The number does not require to be made good, because no reduction in the number of chromosomes occurs in parthenogenetic eggs. The eggs contain the same number of chromosomes as all the other cells of the body.

In order to understand this properly, we must recall what we learnt in Chapter III of the ripening of an ordinary, non-parthenogenetic egg. When the egg is fully grown, the peculiar reducing division takes place, in which the pairs of chromosomes separate partner from partner, so that each of the products of division has the halved number. The two products of division are not equal, as in ordinary

cell division. One is practically as big as the egg was before the division occurred; the other is the minute "polar body," which perishes with its load of unwanted chromosomes. Then another division occurs, which resembles the last in that it is unequal, for a second minute polar body is budded off; but it differs from it in that each chromosome divides as in an ordinary cell division.* The second polar body also decomposes.

Now in the ripening of a parthenogenetic egg only one polar body is formed, and there is no reduction in the number of chromosomes. The single polar body corresponds with the second polar body of ordinary eggs, and the reducing division which characterizes the formation of the first polar body never takes place. The ripe egg has therefore the same number of chromosomes as its mother, and therefore the individual into which it grows has the same number. Since it has the two sex chromosomes of its mother, it grows into a female.

At once another question, a question of sex determination, arises: "How do males ever arise from parthenogenetic eggs, if these eggs contain the same sex chromosomes as the necessarily female individual which produced them?" Careful investigation has shown what happens. When the polar body of an egg which will grow into a male is formed, all the chromosomes except the two sex chromosomes behave as is usual in parthenogenetic eggs, *i.e.*, each divides, and one product of division stays in the egg while the other passes into the polar body. But the sex

* Probably the function of this second division is merely to reduce the thickness of the chromosomes; for they have been growing during the later part of the ripening process, and the reducing division of course did nothing to restore their normal thickness.

chromosomes do not divide. One of them stays in the egg *and the other passes into the polar body*. The result is that the egg is left with only one sex chromosome, and so it grows up to be a male.

The sexual female has the same chromosomes as the parthenogenetic female, so that it raises no problems in this connection; but one question still remains: "How is it that fertilized eggs always grow into females, never into males?" One would naturally expect that the male would produce two classes of sperms—those containing and those not containing a sex chromosome. These, fertilizing eggs all of which contained one sex chromosome (for the sexual eggs undergo a reduction division and have the halved number of chromosomes, with one sex chromosome), would produce two types of individual, one type having two and one type having one sex chromosome. These two types of individual would, of course, be male and female respectively. But as we have seen, fertilized eggs *all* grow into females. The problem is solved when we examine the testis of the male parent. The two classes of young sperms are formed, but those containing no sex chromosome are small and never become properly shaped and functional. The only functional sperms are those which contain a sex chromosome, that is, the female-producing sperms.*

The type of parthenogenesis that we have been discussing is called "obligatory" parthenogenesis, because

This account of the chromosomes in parthenogenesis applies to the plant-lice. In the wheel-animalcules matters are different, for males are produced (as in bees) from unfertilized eggs *which have undergone a reduction division* and which thus have the halved number of chromosomes. Females, on the other hand, are produced (as in plant-lice) from unfertilized eggs which have *not* undergone a reduction division.

the eggs laid by the parthenogenetic females *must* develop parthenogenetically: they cannot be fertilized. Let us turn now to "facultative" parthenogenesis; here every egg *can* be fertilized but can equally well grow up without fertilization. The bees provide the simplest instance.

PARTHENOGENESIS AS A MEANS OF SEX DETERMINATION

A hive of bees contains one fully-developed female or "queen," a large number of sexually-undeveloped females or "workers," and a much smaller number of males or "drones." Fertilization does not take place in the hive, but high up in the air. When the queen leaves the hive on her nuptial flight, all the drones in her own hive and many from neighbouring hives follow her, vying with one another in their efforts to reach her and copulate. One only is successful, and he pays for his success with the loss of his entrails and consequent death. The unsuccessful drones return to the hive with the queen. Their wings are bitten off by the workers, and they are cast out of the hive. Wingless, return is almost impossible to them, and they die of starvation and cold. Should one of them succeed in attaining the hive once more, it is slain. The delights of a drone's existence may be commended as a study for those who believe in a Benevolent Plan in nature.

But let us return to the queen. In the brief moment of her conversion from bride to widow, she receives from her ill-fated spouse sufficient sperms to last her the rest of her^d life—sufficient to fertilize a million eggs. These

she stores in a special bag within her body. The bag opens into the tube down which the eggs pass on their way to the exterior. Round the opening of the bag is a muscle, comparable with the string which closes the opening of a sponge-bag. When this muscle contracts, the bag is closed, and no sperms can escape.

On her return to the hive the queen settles down to her immense task of laying her million or so eggs. The compartments in which she lays them are of three sizes. The largest compartments are those in which new queens will appear. The compartments for drones are rather smaller. Still smaller and more numerous by far are the worker-compartments. When the queen is about to lay an egg in a queen-compartment or a worker-compartment, she allows the muscle which closes the sperm-bag to remain uncontracted. (This is probably a reflex action, comparable with the outflow of saliva on the sight of food in man.) As the egg passes the opening of the bag, it is accordingly fertilized. But when she is about to lay an egg in a drone-compartment, she contracts this muscle, so that the sperms cannot reach the egg. The result is that the egg is laid unfertilized. In bees, *unfertilized eggs grow into males*. Every fertilized egg has the *potentiality* of growing into a queen and of growing into a worker, but only those eggs that receive special after-treatment actually grow into queens. The special after-treatment consists in feeding the developing larva with a particular sort of food which the workers elaborate and put into the queen-compartments. An egg taken from a worker-compartment and placed in a queen-compartment would grow into a queen, because it would receive "royal" food; and similarly an egg taken

from a queen-compartment and placed in a worker-compartment would grow into a worker, owing to lack of this food.

The outcome of all this is that in bees fertilized eggs turn into females (queens and workers) and unfertilized eggs into males. All the eggs are capable of fertilization, so that the production of males from the unfertilized eggs is called "facultative" parthenogenesis. In the ripening of the eggs, the reduction division takes place as in ordinary eggs, so that each egg has the halved number of chromosomes. How, then, is the number made up in the males? The answer is that at first it is *not* made up. A male bee begins to grow up with the halved number of chromosomes in every cell in his body, and it is the possession of only the halved number that determines his maleness. This method of sex determination is, of course, radically different from the usual method. Later in life the number is doubled in an unknown way in some of his tissues, but other cells, among them the cells of the testis, retain always the halved number.

In the ripening of the sperms of ordinary animals a reducing division occurs, in order that the number of chromosomes may be halved. But if such a division were to occur here, the number in the ripe sperm would be a *quarter* instead of a half of the full number characteristic of the female, for the cells which give rise to sperms have only half the number already. It is interesting to note what happens in the ripening of the drone's sperm. The cell which is to give rise to sperms goes through the usual processes as though preparing for a reducing division. But at the crucial moment, it seems, so to speak, to think

better of it ; and instead of a proper division taking place, only a minute portion of the body of the cell is separated off, without any chromosomes. The halved number of chromosomes is thus retained.

From this account it must be obvious that the advantages of parthenogenesis to the wheel-animalcule, the water-flea, and the plant-louse, are not the same as to the bee. To the latter parthenogenesis is a means of sex determination : to the former animals it is an adaptation to rapid multiplication of isolated individuals.

It should be noted that an egg which develops without a reduction division and without fertilization contains precisely the chromosomes of its mother. Variation by recombination of factors is impossible.

ARTIFICIAL PARTHENOGENESIS

What nature does in certain groups of animals, man can do artificially in other groups. Artificial parthenogenesis—the activation of an egg which normally only develops after a sperm has fused with it—can be brought about in a variety of different ways. If the eggs of the sea-urchin are treated first with a solution of butyric acid for a few minutes and then for a quarter-of-an-hour with over-strong sea water, made by adding some common salt to ordinary sea water, they develop as though they had been fertilized. It appears that the butyric acid begins to decompose the surface of the egg slightly. Many substances which have this effect also initiate cell-division. If the decomposition

be carried too far, however, the egg dies ; but in the experiment the decomposition is checked at the right moment by the over-strong sea water, which does not prevent the continuation of the process which the butyric acid started. This explanation is the one put forward by the inventor of the technique. Others have suggested different explanations, which do not associate the decomposing effect of the butyric acid with its power to initiate cell-division. They regard the decomposition as incidental to the process. One authority supposes that there is a definite substance within the egg which is responsible for starting cell-division. It cannot exert its effect, however, until it has been acted upon by another substance. This substance is carried by the sperm. Other substances beside the one carried by the sperm have, however, the same property of making the substance in the egg active. Butyric acid is one of these. A point in favour of this theory is the fact that when eggs are washed repeatedly they lose the power to be fertilized. It is as though the substance in the egg which starts cell-division were washed out of the egg.

CONCLUSION

In this chapter we have wandered from sexual reproduction to realms where reproduction is not sexual ; and we have found that the natural process can be imitated artificially by man. We have found that parthenogenesis is sometimes an adaptation to rapid multiplication, sometimes a means of sex determination. We have noticed

that in some cases all eggs have the power to develop with or without fertilization ; whereas in other cases certain eggs develop only if fertilized, while others cannot be fertilized. We have followed how the chromosomes surmount the difficulties which parthenogenesis puts in their way.

CHAPTER VIII

SEX RATIO

INTRODUCTION

WE have seen that there are two classes of sperms, one class bearing a sex chromosome and the other class bearing no sex chromosome, and that these two classes are produced in equal numbers. This being the case, it might be expected that the two sexes would be equal in numbers. Often, however, the sex ratio is not precisely 100 males to 100 females. It is the object of this chapter to reconcile this fact with the numerical equality of the two types of sperm.

DIFFERENTIAL DEATH-RATE OF THE TWO SEXES

The simplest way in which inequality may be brought about is by a different death rate for the two sexes. The two sexes are produced in equal numbers, but one sex, usually the male, is less hardy than the other. This accounts for the inequality of the sex ratio in a large number of fishes and probably in many other animals as well. But in some cases the sex ratio *at conception* is not equality.

THE INEQUALITY OF THE SEX RATIO AT CONCEPTION

In the human race many more boys are conceived than girls. The ratio at birth is about 105 boys to 100 girls,

and evidently the sex ratio at earlier stages is still more unequal, for abortions are in the proportion of about 150 males to 100 females. It is probable that in mankind rather more than 120 males are conceived to every 100 females.

The only explanation of the conception of more boys than girls that fits in with what we have already learnt, is that male-producing sperms have a better chance of effecting fertilization than female-producing ones. Possibly male-producing sperms swim faster than female-producing ones and therefore tend to reach the eggs first. This is by no means an incredible suggestion in the case of mammals, where the sperms have a considerable distance to swim in the tubes of the reproductive system of the female. It is found in many species of mammals that there are two types of sperm as regards size. There is strong presumption that the larger carries a sex chromosome while the smaller does not. If this is so, and if the smaller sperms are able to swim more rapidly than the larger, then the excess of male conceptions over female is explained. It is not unlikely, however, that it is activity in fertilization rather than speed in swimming that is concerned.

The fact that there is some sort of competition between sperms is shown by an interesting experiment on rabbits. Two male rabbits of differently-coloured races were mated at the same time with the same female. By the colour of the offspring it was possible to tell from which male the sperms concerned in fertilization were derived. It was found that the majority of the offspring resembled one of the male rabbits in colour and*relatively few resembled the other. Evidently the sperms of the former were

more active in some way or another in achieving fertilization. Of course in this case the competition was between sperms of different races of rabbits, but it lends plausibility to the idea of competition between sperms of different sex-potentialities.

If one of the two types of sperms tended to live longer than the other or to stand unfavourable conditions better, that type would be likely to achieve fertilization more often than the other. In this connection the seasonal variation in the sex ratio of mice is interesting. At the height of the breeding season, young mice are produced in the proportion of 96 males to 100 females. After the real breeding season is over, when but few young are being produced, the ratio is 140 males to 100 females. The explanation may be that at the end of the breeding season many of the sperms die on account of the unfavourable conditions under which they are matured; and the male-producing sperms, being more resistant to these particular conditions than the female-producing, die in smaller numbers than the latter and therefore fertilize more eggs.

Possibly something of this sort may be at work in the case of mankind, for here again the relative number of males born at the time of year when the birth-rate is highest is smaller than during the other part of the year.

THE MOTHER'S INFLUENCE ON THE SEX RATIO AT BIRTH

Despite what has gone before, the mammalian mother is concerned in the matter of sex ratio at birth. The reader will at once remark that this seems irreconcilable

with the fact that all eggs are the same as regards sex-potentiality, and that sex determination rests solely with the sperms. The answer to the seeming paradox is that the female affects the sex ratio *after conception* by causing the death of more embryos of one sex than of the other.

Let us take the case of the effect of the mother on the birth-rate in man.

Young mothers produce relatively more boys than old mothers. Statistics show (see Table) that mothers aged between 18 and 22 years produce about 120 boys to every 100 girls; mothers between 28 and 32 produce about 112 boys to 100 girls; and mothers of 43 and over produce only about 85 boys to 100 girls. Surely, the reader will say, the mother must be concerned in sex-determination!

But a study of abortion shows that she is not concerned in sex determination, but in the pre-natal elimination of the male sex.

When girls between the ages of 18 and 22 become pregnant, only in six cases out of 100 does abortion occur. The number of abortions rises steadily with the age of the mother, until in the case of pregnant women of 43 and over more than 40 embryos are aborted in every 100 conceptions.

| Age of Mother | No. of males born to every 100 females. | No. of abortions to every 100 births. |
|---------------|---|---------------------------------------|
| 18—22 | 119·8 | 6·3 |
| 23—27 | 110·6 | 12·7 |
| 28—32 | 111·7 | 26·1 |
| 33—37 | 112·6 | 29·9 |
| 38—42 | 91·8 | 31·0 |
| 43 | 84·6 | 41·4 |

These figures are taken from a paper by Dr. A. S. Parkes in vol. xiv of the *Journal of Genetics* (pp. 39-47), by kind permission.

If abortions were equally commonly male and female embryos, then these facts would not affect sex ratio. *But* (as mentioned before) *aborted embryos are usually males*, the proportion being about 150 male to every 100 female aborted embryos. Therefore, the more abortions, the fewer males born alive: therefore, the older the mother, the fewer the boys.

Exactly the same state of affairs exists as regards the sex ratio of first-borns compared with the sex ratio of second-borns and later children. In the case of first-borns the number of males is relatively great. The number is less in the case of second-borns, still less in the case of third-borns, and so on. In a parallel way the number of abortions rises from six per cent. in the case of first pregnancies to 44 per cent. in the case of eighth and later pregnancies. The explanation of the fall in the relative number of males is, of course, the same as in the case of the fall in number of males with increasing age of mother.

Now let us turn once more to mice. The sex ratio in small litters is only 84 males to 100 females, whereas in large litters it is 125 males to 100 females. At first sight it might appear that the mother is concerned in sex determination, for certain mothers (those which produce small litters) produce relatively few males, while others (those which produce large litters) produce relatively many. The true explanation is probably differential mortality of embryos. When a small litter is produced, it is usually a sign that many embryos have died before

birth, and have been absorbed in the womb of their mother. Now male embryos die and are absorbed more commonly than female embryos. Therefore, when many embryos die, the number of males is lessened ; and thus small litters contain relatively few males.

It will be obvious to the reader from these examples that the mother is no more concerned in sex determination than Herod was when he ordered the destruction of all first-born sons.

Quite a different way in which the sex ratio may be changed from equality is by recessive sex-linked factors which cause the death of the individual unless corrected by an opposing normal factor. Let the reader imagine a factor inherited in the same way as the factor which causes colour-blindness in man, but so infinitely more serious that it causes death at an early stage of development. For precisely the same reason (p. 62) that colour-blindness is commoner in men than in women, the early deaths caused by this factor will fall preponderatingly upon the male sex. Male delicacy should probably be ascribed to the same cause.

CONCLUSION

In mammals the sex ratio at conception is usually many more than 100 males to every 100 females, because the male-producing sperms are in some way better equipped for effecting fertilization than are the female-producing ones. On the other hand female embryos are much less liable to be aborted than male embryos, so that at birth there is usually only a slight excess of males. The older the

mother, the more abortions, and hence the smaller the proportion of males born alive. The males of many different animals tend to die in early life more commonly than the females, so that the sex ratio of adults often shows an excess of females.

Erroneous ideas about the effect of the mother on sex ratio have given rise to some curious theories as to how sex ratio may be artificially changed. Let us consider what has been guessed and what ascertained upon this most important subject.

CHAPTER IX

THE ARTIFICIAL CONTROL OF SEX

INTRODUCTION

IN the last chapter we saw how it comes about in nature that the number of males does not precisely equal the number of females. In this chapter we will discuss how the sex ratio may be altered artificially.

The problem is an interesting one from a practical point of view. Many prospective parents would rather have a boy than a girl, or *vice versa*, and would like to know whether there is really any way in which they can arrive at the desired result. Perhaps they have heard of an old midwives' superstition in this connection. To the stock-breeder also the possibility of controlling the sex ratio would be an immense boon.

The amount of nonsense that has been written on this subject was emphasized in Chapter III. Mention will be made in this chapter of some of the wilder theories. But first let us deal with facts.

OVER-RIPENESS OF THE EGG AND SEX-CONTROL

In the frog, the process of egg-laying and fertilization is as follows. In the breeding season, the male seizes the

female and holds her with his powerful and specially-padded front limbs until such time as her eggs are ripe and she begins to extrude them. He then ejects sperms over the eggs as they are extruded. The two types of sperms (male-producing and female-producing) are formed in equal numbers, so the sex ratio of the tadpoles which grow from the fertilized eggs is near equality.

But if the male frog be removed from a female which has already extruded some of her eggs, so that the eggs become over-ripe before he is allowed to return to her to fertilize them, there is a surprising result. *The number of males produced is increased.* If the eggs be allowed to become four days over-ripe, *all* the individuals into which they grow are males. Half of them start life as females, but all grow up into males. The case is interesting in view of the fact that there is a species of fish in which *normally* all individuals start life as females, and later half change into males; but as yet it has not been satisfactorily interpreted.

SEX-CONTROL IN MOTHS AND BIRDS

The reader who has read Chapter III is aware that it is only in birds and moths that there are two sorts of eggs as regards sex-potentiality. He will also recall that at the reducing division one large cell is left, while a minute "polar body" is budded off, containing the unwanted chromosomes. In birds and moths the ripening egg has one sex chromosome. At the reducing division that sex chromosome either goes into the polar body or remains

within the egg. In the former case the fertilized egg grows up into a female; in the latter, into a male. Now it is evident that if one could artificially control the direction in which the sex chromosome passes at the reducing division, one would be artificially controlling the sex ratio. This interesting result has been achieved with a certain species of moth. If this moth be bred at the ordinary temperature of the laboratory, the sex chromosome passes out of the egg into the polar body rather more commonly than it remains within it, so that rather more female than male offspring are produced. But if a female is kept at a high temperature during the period when the eggs are undergoing the reducing division, the sex chromosome remains within the egg much more often than not, so that she produces many more males than females. The actual figures are as follows:—

| Temperature | No. of males to 100 females |
|-------------|--------------------------------|
| 18° C. | 74 |
| 35°—37° C. | 161 |

The reader will remember that pigeons normally lay two eggs in a clutch, and that the first is small and grows into a male, while the second is large and grows into a female. As was pointed out in Chapter III, the most probable explanation is that the chemical composition of the first egg causes the sex chromosome to remain within it at the "reducing" division, while the composition of the second egg tends to make it pass out into the polar body. One may interfere artificially with this regular production of a male from the first egg and a female from the second, by crossing two pigeons of different genera. When this

is done, males only are produced at the beginning of the season. Later on females also appear, and finally only females are produced. One may interfere further by removing the eggs as they are laid and thus forcing an abnormally large egg production. The effect is that the switch over from male-production to female-production comes earlier in the season. These very interesting facts have not yet met with any satisfactory explanation bringing them into line with what is known of the mechanism and physiology of sex determination in other animals.

A THEORY OF SEX-CONTROL IN CATTLE

A theory has been advanced that in cattle the sex of the embryo depends upon the time of fertilization in relation to the period of "heat." The theory is that cows which are served early in the period of heat tend to produce females, while those which are served late tend to produce males. If this were true, the case might be comparable with the case in frogs just described. It would also be explicable on the supposition that the egg varies in the readiness with which it may be fertilized by each of the two types of sperm. One would have to suppose that at first it is most readily fertilized by female-producing sperms, and that as time goes on changes take place in the chemical composition and physical condition of its surface which render it more easily fertilized by male-producing sperms. However, the latest statistics seem to prove that time of service has no effect upon sex.

SUPPOSED METHODS OF SEX-CONTROL IN MANKIND

A very similar theory has for long been held by midwives to apply to the human race. Since midwives have, as a rule, no means of obtaining a sufficiently large body of accurate facts bearing upon the subject, and since they must usually have but the scantiest idea of the laws of chance and their application to statistical enquiry, we may safely neglect them and wait until the matter has been more fully investigated before making up our minds. There are only two possibilities when a child is about to be born, and it is but human nature for midwives to remember their successful guesses and to forget their unsuccessful ones. In the course of conversation between midwives it would be only the successful guesses—the ones that fitted in with the old superstition—that would be mentioned, and thus a random theory with no backing in solid fact might easily come to be widely spread. If it be argued that there must originally have been some reason for preferring the supposition that conceptions soon after menstruation usually lead to boys to the reverse supposition, it may be queried why it is a *black* cat which spells good fortune rather than a tortoiseshell one, or why a floating tea-leaf brings a visitor, whereas a coffee-ground does not. Instances of arbitrary decisions in superstitions could be multiplied.

Most elderly people have remembered their coldest winters and hottest summers and have forgotten the ordinary ones. They are, therefore, of opinion that the seasons are becoming progressively less seasonable; but

the unpleasantly uncompromising thermometer assures us that no such progressive change in climate has occurred since temperature records have been kept. Anyone who has made up his mind that the weather is not what it was in "the good old days" is much impressed by any modern winter which happens to be unusually mild, *because it fits in with his theory*. His theory starts by the remembrance of the remarkable and goes on by the remembrance of all facts which fit in with it but of none which do not. In the same way the midwife, who knows the old superstition at the beginning of her career, remembers the cases which agree with it and minimises the importance of those which do not, either by forgetting them or by doubting the accuracy of what the mother told her about the date of conception. We must not think that the midwife is particularly foolish for allowing herself to be led astray like this by a superstition, for nearly every supporter of a political party acts in precisely the same way. Having for some insufficient reason chosen a party to which to adhere, he remembers what good is done by his party and minimises, disbelieves, or forgets the harm, whereas he exaggerates, to an absurd degree, the faults of the opposing party, and will not listen to anything in its favour. In order completely to shut himself off from the possibility of having to weigh the merits of both sides of a question in his own mind, he reads only those newspapers that support the policy of his own party. It has been necessary to follow this little digression to see how utterly uncritical most people are, and, therefore, how easily a superstition may gain ground.

There is one particular way in which the superstition

in question is fostered. Certain married people unite only at the period which is prescribed for the production of boys. Quite naturally, and in accordance with the laws of chance, some of these couples produce three or more boys running and no girls ; and their evidence is taken by the credulous as almost proving their contention that they can control the sex of their offspring. Of course, in point of actuality pure chance gives three boys running to one couple in every eight couples who have three children.* In order to support their contention, one would have to study the families of an enormous number of couples who only unite at the prescribed time and who have three children, and to see whether in their case more than one couple in every eight have all three children boys. Till this is done, the instances cited in the papers are of negligible interest.†

Another superstition exists to the effect that the ovary of one side produces male eggs and the ovary of the other side female eggs. A similar guess applies to the male parent, one testis being supposed to procreate boys and the other girls. Unilateral ovariectomy and castration completely disprove these theories. Another idea is that if a man is of stronger character or constitution than his wife, he will tend to have more boys than girls, and *vice versa*. I have also heard the view expressed that in animals

* This is assuming a birth rate of 100 males to 100 females. Actually rather more boys are born than girls, so that chance gives three boys running to rather more than one couple in every eight couples who have three children.

† Since in women the time at which an egg bursts from the ovary bears no exact relation to the time of menstruation, it follows that the length of time elapsing from menstruation to coition bears no relation to the age of the egg at fertilization. Thus the superstition gains little or no support from the experiments on frogs described at the beginning of this chapter.

as well as in mankind, the parent whose sexual instincts are the stronger tends to have children of his or her own sex. Why this has not resulted in the enormous numerical superiority of the male sex, I do not know. Of course, everyone is well aware that many mothers think that they can determine the sex of their children by the exertion either of the will or of the imagination. These imaginary extensions of the powers of Christian Science and auto-suggestion respectively do little credit to their propounders.

ACTUAL SEX-CONTROL IN MAMMALS

Only two instances are known of the artificial control of the sex ratio at conception in mammals. As was pointed out in the last chapter, the sex ratio at birth is a different matter. If the mother is ill-treated in any way, she is more likely to produce abortions than if she were well cared for. Abortions being usually male, the proportion of females is increased by ill-treatment of the mother. Conversely, favourable conditions increase the number of males born alive. One of the most important favourable conditions is the proper spacing of births. When children are not born too soon after one another, the mother remains in a favourable state for the production of living young; therefore the number of abortions decreases; therefore the proportion of males born alive increases. This is what happens in war time, when, as everyone knows, the proportion of boys born increases very slightly.* The reason

* The increase in England and Wales during the European War was about 2 per cent.—that is, about 2 more boys than usual were born to every 100 girls.

is that separation of husbands from wives decreases the number of children born. Mothers are thus given a chance of producing living boys who would have died before birth if their conception had followed too quickly upon the birth of the previous child. But this is not really an example of the artificial control of the sex ratio ; it amounts merely to the saving of individuals of one sex who would have died under ordinary circumstances.

The first of the two known cases of real sex control in mammals is a most peculiar one. A male rabbit was placed during a single day with no fewer than twenty different females, one after another. It copulated with each one. The sex ratio of each of the twenty resulting litters was noted. This experiment was repeated several times, and the average sex ratio of each litter, from the first to the twentieth, was obtained. The result is shown by the table. It will be noticed that the relative number of males goes down enormously from the first female served to the last. In the litter resulting from the first copulation, the sex ratio is 129 males to 100 females ; in that resulting from the twentieth, it is 28 : 100. This case has not been explained. Perhaps the conditions within the testis are altered by continued copulation, and in the altered conditions the male-producing sperms tend to be rendered ineffective.

| | 1st Copulation | 5th Copulation | 10th Copulation | 15th Copulation | 20th Copulation |
|---|-------------------|-------------------|--------------------|--------------------|--------------------|
| Number of males to every 100 females | 129 | 77 | 80 | 53 | 28 |

In the second case a modification of the father's diet had the effect of altering the sex ratio. For the proper

health of an animal it is imperative that its food should contain minute amounts of three substances, called vitamins A, B, and C, which exist in such foods as milk, green vegetables, and the husks of rice. Vitamine B is the one which concerns us here. Deficiency of vitamine B causes the disease known as beri-beri, in which the nerves become inflamed and finally degenerate. It is commonly caused by the eating of "polished" rice to the exclusion of other substances. Since the husk is removed in the "polishing" process, and since vitamin B exists in the husk only, people subsisting on this foodstuff obtain no vitamine B whatever.

If male rats are kept on a diet which has not sufficient of vitamine B for perfect health, it is found, particularly after the end of the first month of treatment, that the sex ratio of the litters which they father is changed from the normal, which is in the neighbourhood of 100 : 100, to as few as 73 males to every 100 females. One must conclude either that there is a greater tendency for the male-producing than for the female-producing sperms to be rendered incapable of effecting fertilization, or that the male-producing sperms are affected in such a way that the embryos to which they give rise tend to die before birth and to be absorbed within the womb of their mother. That the first alternative is the right one is shown by the fact that the litters are not smaller than ordinary litters, as they would be if a number of male embryos had died off.

Another interesting piece of research should be mentioned here, although perhaps it can hardly be considered as a third case of sex-control in mammals. It was found that by always breeding from those individuals which produced

the greatest proportion of males, a strain of rats could be produced in a few generations which gave a sex ratio of about 120 males to every 100 females. In the same way, by selecting rats which produce particularly few males, a strain could be produced which gave a sex ratio of only about 80 males to every 100 females. This case has not been satisfactorily elucidated. Possibly in certain female rats the chemical and physical environment within the genital tract is favourable to male-producing sperms, while in other females it is favourable to female-producing ones. If so, selection would produce the two strains provided that the condition of the genital tract is an inherited character.

The methods of sex-control in mammals which I have described do not appear to lend themselves to practical use. Perhaps a method will be devised by which ejaculated sperms might be separated more or less roughly into the two types, male-producing and female-producing. In live-stock ejaculated sperms can be obtained from the vagina of a female which has just been served. The technique might be to subject the sperms to conditions which were more unfavourable to one type than to the other. The type that withstood the treatment best could then be injected into the vagina of a female, possibly after some restorative process. Again, the sperms might be allowed to swim along a tube until the difference in their rate of movement had separated the two types. They could all be orientated to swim in the same direction either by an electric current, or by passing a very slow current of the medium in which they were suspended along the tube, for sperms turn to swim against a current. So far, technical

difficulties have brought failure in experiments of this sort, but success will probably be achieved in the not very far-distant future.

CONCLUSION

It has been shown that the sex ratio may be artificially controlled in several animals. In a certain moth, increased temperature causes the sex chromosome to stay within the egg at the reducing division much more often than not, so that it increases the proportion of males. In frogs, delayed fertilization makes many eggs grow into males which would ordinarily have grown into females. Generic crossing and a forced egg-production affect sex ratio in the pigeon. Repeated copulation and deficiency of vitamin B lower the percentage of males in rabbits and rats respectively. Conclusive evidence that sex can be controlled in mankind has not been produced. Technical difficulties have so far prevented the separation of male-producing from female-producing sperms.

Since this book was written it has been found by Dr. A. S. Parkes that the sex-ratio can be artificially controlled in mice by treatment for short periods with X-rays. A male mouse which has been irradiated produces first an excess of males and subsequently an excess of females. This case has not yet been explained.

CHAPTER X

SEX BEHAVIOUR

INTRODUCTION

THE foregoing part of this book, resting as it does on a solid basis of fact, contrasts markedly with this last chapter, the greater part of which is concerned with social anthropology and psychology. In these two sciences, particularly the latter, there is a large amount of hypothesis and relatively little fact. It is obvious that when more is known and less guessed in these sciences, they will become of very great importance.

BREEDING SEASONS

Most animals from the lowest to the highest have a particular breeding season during which their reproductive activities are greatest. A curious exception among the higher animals is the white-footed mouse of North America, which breeds all the year round in the wild state, although allied genera have a definite season. Many domesticated animals, such as the pig, are bred from at all seasons of the year, but this is an unnatural proceeding. In the great majority of cases the eggs are fertilized during a more or less restricted and definite period of the year, so chosen that

the young grow up at the time when conditions are most favourable to them. In the case of the mammals, whose young are carried within the bodies of their mothers until development is far advanced, the mating season is often far removed from the period when the young are born. This is especially the case in large mammals. In mankind there is still some slight remnant of a breeding season, for the number of births (in Europe) is higher in February and March and again in September and October than at other seasons. The Esquimaux are said to have a more definite season of childbirth than any other race. In this connection also it is interesting to note that among certain nations the feasts at which sexual licence is greatest occur during one definite period of the year.

COPULATION

In many of the more primitive animals there is no difference in behaviour at the breeding season, except that the sperms and eggs are ejected to the exterior. It is merely chance that brings sperms and eggs together, and there is no special behaviour between individuals of opposite sexes at all. The enormous waste of material necessitated by this method is obvious. In the course of evolution animals began to associate together when about to discharge their sperms and eggs. They reaped the benefit that it was no longer necessary to produce such abundance of gametes, for the chances of fertilization were greatly increased. A later modification was a specialization of this method, namely, the coming together of individuals in pairs at the

appropriate time. This instinct became particularly strong in the male sex, which often acquired special clasping organs for holding the female. Lastly, the male acquired a copulatory organ, which, introduced into the body of the female, ensured the least possible wastage both of sperms and of eggs. The passage of sperms from the male into the body of the female, which is so advantageous a process to all species which practise it, is a necessity for all terrestrial animals ; for wind fertilization and fertilization by the agency of some other organism are confined to the plant kingdom.

Pleasure is experienced in the satisfaction of any instinct, and more so in the case of the sexual instinct than of any other. To speak teleologically, the pleasure of copulation—which, as Darwin pointed out, is experienced even in earthworms—has been evolved in order to ensure the survival of the race. If in any species there were insufficient inducement to copulation, that species would obviously die out.

Among the lower animals which practise copulation, there is no association together in pairs between one copulation and the next, and a given individual does not tend to copulate more than once with the same individual. Higher animals often associate in pairs, either for the breeding season only, as in many birds, or for an indefinitely long period, as in certain birds, as well as in the anthropoid apes and mankind.

COURTSHIP

In cases where such association occurs, there may or may not be some form of courtship before the pairing off ; but

whether there is association or not, there is very commonly a courtship preparatory to each copulation.

A certain crab illustrates a type of invitation to copulation which is so primitive as hardly to deserve the title of courtship. During the breeding season the male seizes upon any female with whom he comes in contact and holds her tightly. The female is only prepared to receive the male directly after moulting. If she is not in this condition, she struggles violently and eventually escapes. If she happens to be in the right condition she submits.

The fiddler crabs illustrate a primitive form of courtship which may be called "advertisement" courtship. The male attracts the female by suddenly thrusting out his enormous claw. Just as the technique of advertisement has progressed from a few words in enormous block letters to most subtly-worded inducements to buy, so the ceremonies of courtship have improved from such small beginnings as are exemplified by the fiddler crab to the truly wonderful love-makings of many birds. To any one who has not personally witnessed the highest forms of courtship, it is almost incredible that birds should go through such complicated manœuvres to charm their mates. Sometimes it is only the male that courts; sometimes, as in herons and grebes, both sexes participate equally.

MARRIAGE

To associations between male and female animals the term "marriage" may properly be applied. I define marriage as the association together of one or more indi-

viduals of one sex with one or more individuals of the other sex, with freedom of repeated sexual intercourse. The biological significance of marriage is twofold. Firstly, the chance that a female in heat should fail to be impregnated is lessened ; secondly, the mother and young secure the advantage of protection by the father.

In the Louisiana Heron certain remarkable displays take place in the breeding season, which are equally participated in by the male and female of an already mated pair. These displays have been termed "self-exhausting," for they do not lead to copulation nor to anything else. Their biological significance is that they serve to keep male and female together at a time when their separation would be prejudicial to the welfare of their offspring. Such displays are comparable with the innumerable actions unconnected with sexual intercourse which serve in mankind to keep husband and wife together.

The type of marriage characterized by the association of one male with one female, as in many birds and mammals and some of the higher races of mankind, is called monogamy. Polygamy, on the other hand, is the association of one individual of one sex with more than one individual of the opposite sex at the same time. Polygamy may be either polygyny or polyandry, according to whether one male is associated with several females or one female with several males. Polygyny occurs in many birds and horned mammals, and in most primitive and many civilized races of mankind. In mankind it has the obvious disadvantage that it leads to much male celibacy and puts women in an undeservedly inferior position. This reaches an extreme in India, where the Hindus regard women as designed simply

for the pleasure and comfort of man. Polyandry occurs rarely in animals,* and in man only among the Tibetans, the Todas of the Nilgiri Hills in India, the Marquesas Islanders, and a few others. Often it is merely a modification of the widely-spread custom according to which a widow marries her late husband's brother, for all the husbands of a single wife are brothers. Group marriage is the association of several males with several females and must be distinguished from promiscuity. As we shall see, it was probably practised by primitive man.

It is doubtful whether there is any race of mankind to-day which is without the institution of marriage. Nevertheless, it has been supposed by some anthropologists that the ancestral man lived in a state of sexual promiscuity. The most important piece of evidence on the original state of mankind as regards marriage is derived from the classificatory system of relationship-notation, which is used by most primitive races. Before considering this subject, I will briefly review the rest of the evidence for and against the hypothesis that primitive man was promiscuous, taking the arguments in favour of the hypothesis first.

(1) Many travellers have reported cases of tribes living promiscuously. (2) It is well-known that promiscuity before marriage is common in many savage tribes. (3) Many savages who have the institution of marriage are none the less very licentious. (4) There are many cases of women being required to give themselves up to promiscuous intercourse once during their lives, often on the first

The marine Annelid *Bonellia* is an example. Several males live parasitically within the body of a single female.

night of their marriage, as though in atonement for living monogamously thereafter. (5) Savages often lend their wives to guests, or prostitute them for gain. (6) In ancient Athens courtesans were held in high esteem, whereas the real wives were treated as servants. (7) It has been argued that kinship through the female line, which is common in many primitive peoples, is inexplicable except on the assumption of promiscuity ; for men would insist on their children being of their kin if it were always possible to say who was the father of a given child.

Those who believe that primitive man was monogamic or polygynic give the following answers to these arguments :

(1) Few travellers are qualified to speak of the sexual relationships of primitive people, and in nearly every case it has been shown that their statements are entirely false, or that they have confused the lending or prostitution of wives with promiscuity. (2) Premarital intercourse is often severely punished by savages. (3) The licentiousness of savages is usually caused by the advent of the white man. Licentiousness is not found in tribes living entirely outside the reach of white influence. (4) The obligation for women to give themselves up to promiscuous intercourse is not found in primitive tribes. (5) The lending of wives is merely hospitality ; it no more indicates promiscuity than the giving of food and shelter to a guest indicates a previous condition of communism in property. (6) Ancient Athens cannot be expected to throw more light on the condition of primitive man than any European capital to-day. (7) Many primitive tribes are patrilineal ; and it is not surprising that most are matrilineal, for even when the actual father is known the relationship between mother

and child is much more obvious and enduring than that between father and child.

A few other reasons are urged against promiscuity, namely, that promiscuity would assume no inherent jealousy in mankind despite the fact that jealousy does exist in primitive people; that the anthropoid apes, the nearest relatives among animals of primitive man, appear to be monogamous; and that promiscuity leads to infertility and therefore the human race would have died out if ever promiscuity had been general. The last argument is not, however, very cogent; the well-known infertility of prostitutes must be ascribed rather to the use of contraceptives than to promiscuous sexual intercourse.

The classificatory system of relationship-notation gives much more weighty evidence on the problem than any of the previously-mentioned arguments. It is used by the natives of the Pacific Islands, New Guinea, Australia and North America, as well as by some of the inhabitants of Africa and India—in short, by nearly all the most primitive as well as some of the more advanced peoples. It differs from the "family" system, which is used in Europe and elsewhere, in that there are no special words for "father" or "mother," each of these two relatives being classed with a large number of others, some of whom we would regard as distantly related or as unrelated.

A feature of many of the most primitive forms of society is that the members of a tribe are divided into two groups called "moieties." Everyone knows to which moiety he or she belongs, and to which moiety each of his or her acquaintances belongs. Each moiety is "exogamous;" that is,

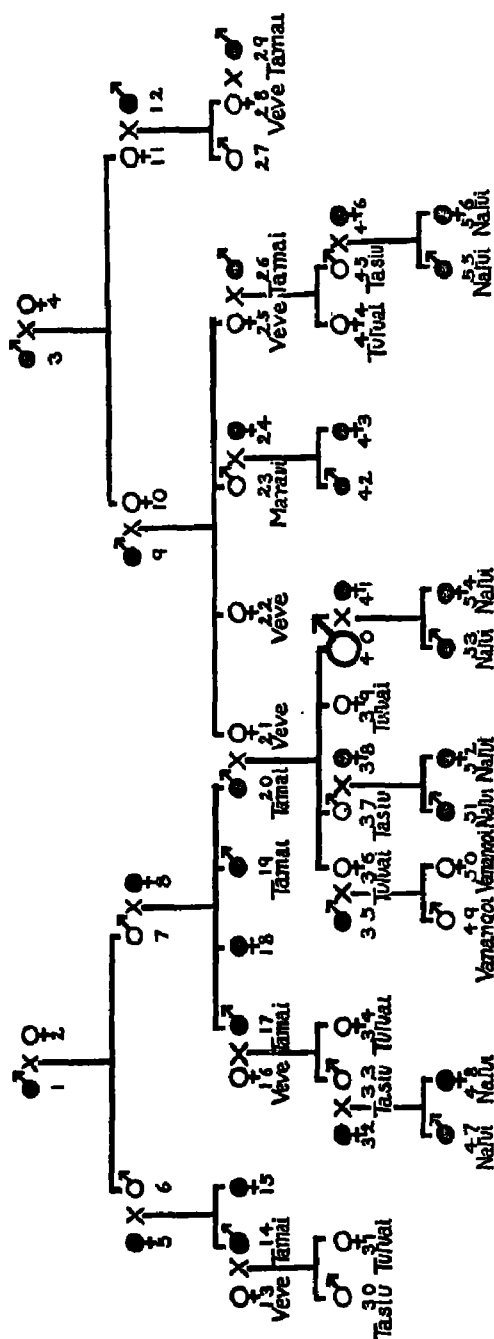


FIG. 22.—DIAGRAM ILLUSTRATING THE SYSTEM OF RELATIONSHIP-NOTATION USED BY THE BANKS ISLANDERS. THE WORDS DENOTE THE RELATIONSHIPS IN WHICH THE VARIOUS INDIVIDUALS STAND TO THE MAN NUMBERED 40. FOR FURTHER EXPLANATION SEE TEXT.

no one may marry a member of his or her own moiety. In what are called "matrilineal" societies—and most primitive tribes are matrilineal—each child belongs to his or her mother's moiety. Other tribes are patrilineal.*

In order to render the classificatory system easily understood, I give here as an example the terms used by the natives on the Banks Islands (the most northern islands of the New Hebrides in the Pacific Ocean). The system in the Banks Islands is matrilineal.

Fig. 22 represents an imaginary family of Banks Islanders. The sign ♂ indicates a man, the sign ♀ a woman. The blacked-in signs (♂ and ♀) indicate members of one moiety; the unblackened signs (♂ and ♀) indicate members of the other moiety. Each person is distinguished by a number written under his or her name. The words written under the signs indicate the relationship in which the various people stand to the man (40), who is distinguished by a much larger sign than the others.

The first thing to notice is that there is no special term for the man's father. No. 40 applies the word "Tamai" to the following people :

1. His father (20)
2. His father's brothers (17 and 19)

* Sometimes each moiety is divided into a number of "clans" (also called "septs"), each of which is distinguished by some emblem, it may be an animal or a plant, called a "totem." Other tribes are divided into clans without any division into two moieties; in this case a member of one clan may marry a member of any other clan. Usually the members of a clan elect a council with legislative authority; but a moiety never has any political significance. In this discussion I deal only with the moiety, not with the clan.

3. His father's cousins in the male line (14)
4. The husbands of his mother's sisters (26)
5. The husbands of his mother's cousins in the female line (29)*.

Quite similarly, he has no special word for "mother," but classes the following relatives together as "Veve":

1. His mother (21)
2. His mother's sisters (22 and 25)
3. His mother's cousins in the female line (28)*
4. The wives of his father's brothers (16)
5. The wives of his father's cousins in the male line (13)*.

In the same way he classes as "tasiu" or "tutuai" (according to sex†):

1. His brothers and sisters (36, 37 and 39)
2. His cousins of the same moiety as himself (30, 31, 33, 34, 44 and 45).

As "natui" he classes:

1. His own sons and daughters (53 and 54)
2. The sons and daughters of his brothers (51 and 52)
3. The sons and daughters of his male cousins (47, 48, 55, and 56).

There are other names for grandparents and grandchildren and for various "in-law" relations. A particularly important relationship is with the sister's children (49 and 50), whom he calls "vanangoi," while he is "maraui" to them (just as 23 is "maraui" to him). A maraui is his vanangoi's adviser and protector, and his sponsor at

* In the diagram only the first cousin is shown, but the same applies to the second and third cousins.

† Men are "tasiu" to one another; so are women to women. But a woman is "tutuai" to a man, and so is a man to a woman,

initiation ceremonies ; in some tribes he has also to share his property with him. But the relationships of tamai and veve are the important ones for us on account of their bearings on the promiscuity hypothesis.

The implication of the fact that a man classes his father with his father's brothers and cousins (and, indeed, often with all the other men of the same generation of the opposite moiety to his own), is that in more primitive times his mother was allowed sexual intercourse with all the men of the opposite moiety and of about the same age, and that it was impossible to say who was the actual father of any child.

From the fact that a child calls a large number of women by the same name as his or her mother, it has been concluded that in earlier stages of culture the children, having been weaned before they were able to speak, were thereafter looked after equally by all the women of their own moiety, so that no one knew who was his or her actual mother.

This line of argument gives strong support to the idea that in primitive times all the men of one moiety were allowed freedom of sexual intercourse with all the women of the same generation of the other moiety, and that the children were cared for communally by the members of their moieties and did not know their actual parents. This would, of course, constitute "group-marriage." Though the conjecture that a mother did not know her own child is at first acquaintance almost incredible, yet many anthropologists who have studied primitive races regard it as very probable.

In the Hawaiian Islands a much simpler form of relationship-notation exists than elsewhere, for a man calls his

mother's brother by the same name as he calls his father and father's brother, and he calls his father's sister by the same name as he calls his mother and mother's sister. If this were a relic of a primitive system of relationship-notation, it would mean that formerly any male relation of the next older generation might be one's father—that is, that there was complete promiscuity in the family and possibly in the tribe. But it has been shown with a great deal of probability that this simple system is not primitive at all, but a comparatively modern degeneration from an older more complicated system.

Careful study of systems of relationship-notation has given rise not only to the group-marriage hypothesis, but also to other curious theories about marriage in early stages of man's history. For instance, it has been rendered almost certain that after group-marriage was abandoned the inter-marriage of cousins became customary. In the Island of Raga, in the New Hebrides, it was formerly correct to marry one's grand-daughter in addition to one's other wives.

An extreme case of marriage between close relatives is, of course, provided by the Pharaohs of Egypt, who married their sisters.

Before leaving this subject, I should state that many distinguished anthropologists are opposed to the group-marriage hypothesis, and consider it probable that ancestral man practised monogamy or polygamy.

In mankind marriage is effected either by purchase, by parental arrangement, by mutual desire, or by some combination of these, and is nearly always attended by some form of ceremony. Marriage by purchase is very common

in primitive races, the bridegroom paying the bride's relatives in money or in kind for the privilege of taking her from them. Parental arrangement with no power of decision allowed to the parties themselves is not common in primitive man, though in some cases betrothals are made when the prospective life-partners are but a few years old or even before they are born. This happens particularly in polygamous races, when a man fears that his son may be unable to secure a wife. In civilization parental arrangement is often important. It is sometimes combined with a modified form of marriage by purchase, for the magnitude of a prospective bride's "dot" certainly influences her selection. As regards the marriage ceremony, it very frequently happens among the most diverse nations* that a mock fight takes place, the bride being actively sought by the bridegroom and his friends, while her relatives try to keep her from him. It is unlikely that this is a relic of a time when men forcibly took wives against the latter's will, for there is no evidence that a time ever existed when such a custom was widely spread. Probably it is a memory of marriage by purchase, and the bride's defenders are pretending to insist upon their right of recompense before parting with her.

THE SEXUAL INSTINCT IN MANKIND

In mankind, as in nearly all animals, the sexual instinct of the male is stronger than that of the female. The

* *e.g.* among the Mosquito Indians, certain of the equatorial African tribes, and some of the Pacific Islanders. Formerly also among the Teutons, Romans and Welsh. Until recently among the Russians.

difference in intensity is usually exaggerated by keeping knowledge of sexual matters from girls, or by suggesting that there is something evil in them.* Repression of the sexual instinct hinders its proper development and often results in sexual frigidity. Many women are wholly without sexual feelings as a result of repression in youth. Under the curious misnomer of "innocence" this lack of the sexual instinct was once esteemed a virtue.

Whereas in man the sexual instinct undergoes no periodical variations in intensity with the exception, perhaps, of a slight annual increase in Spring, that of woman waxes and wanes rhythmically as does that of other female mammals. But in other mammals the waning is more marked, for the female's desire cannot be stimulated except at the normal periods of desire, between which she will not receive the male. It appears that in most women desire reaches a maximum about every fortnight, a day or two before and about a week after menstruation; but there is considerable variation among different women, and the period is sometimes monthly instead of fortnightly.

The instinct of self-adornment is a part of the sexual instinct which is deeply rooted in both men and women, and shows itself chiefly in whichever sex has the greater difficulty in obtaining mates. Thus in many polygamous races, where the women have no difficulty in getting married, they are not so vain as the men and adorn themselves less elaborately. The reverse is the case where monogamy is combined with an excess of women.

It is probable that clothes were first adopted as orna-

* This idea, exemplified by worship of virginity as such, takes a prominent part in two quite unrelated religions.

ments. In primitive peoples there is no such a thing as a feeling of shame at nakedness. Clothes are often adopted merely as a means of sexual attraction. In parts of Central Africa nothing is deemed such an emblem of modesty in girls as complete nudity. People who are easily shocked by nakedness are usually those whose own sexual instincts are to some extent ill-developed or perverted.

Primitive peoples render themselves attractive not only by clothes of various sorts, but also by mutilation of the body, particularly of the ears and nose. Circumcision and the piercing of the ears for ear-rings are the last traces of these customs in civilization.

SUBLIMATION

When an instinct is curbed to some extent, the mental energy which would otherwise have been used up in its satisfaction may be made use of in some other beneficial way. This process is known as "sublimation." For instance, the instinct of fear may be sublimated by keeping the mind always ready to meet difficulties should they arise. The sexual instinct is a complicated one, composed of diverse elements, such as self-assertion in the male, submissiveness in the female, and love of admiration in both. These and other parts of the instinct may be sublimated in various ways to the great advantage of the community, if a reasonable check be put upon the sexual desires. For instance, the love of self-assertion finds play in the tactful direction of the work of others by one in

authority, and the love of admiration results in the acquirement of technical proficiency in many who would remain indifferent craftsmen without it. Art and music probably owe much to sublimation of the sexual instinct. The possibility of sublimation is one of the chief reasons why the sexual instinct should not always be allowed free play in its natural consummation.*

FIXATION

It is hardly necessary to stress the fact that the development of the mind from the cradle to maturity is an excessively complicated affair. As far as the sexual instinct is concerned, the child is at first "auto-erotic," that is, its sexual instincts are directed towards itself. Later, in boys of the age of ten or thereabouts, they become directed towards other boys. The sexual instinct at this stage does not normally appear as such, but prompts them to join together in gangs, which are held together by strong feelings of camaraderie. At this stage there is usually great contempt for girls. Later, the instinct becomes one of ill-defined interest in and affection for girls, usually several at the same time, and is combined with an exaggerated pleasure in self-display. Later the instinct becomes more definite and often restricted to a monogamic ideal. A comparable series of stages is enacted in the normal development of the sexual instinct in girls.

* There are, of course, other reasons. The rhythmic waning of desire in women, the contempt bred of familiarity, and the waste of valuable nucleo-proteins in the seminal fluid are others. But it is a perverted view that continence should be practised for its own sake, as though sexual intercourse were evil.

Now, for the normal unfolding of this remarkable sequence, a normal environment is required. It is not very wonderful that sometimes the unfolding does not proceed regularly through all its changes. Psychologists call a sudden stoppage in the development of an instinct a "fixation." Fixation of the developing sexual instinct may occur at any stage, and is often not correlated with failure to develop of any other instinct or bodily character. If fixation occurs in the auto-erotic stage, the individual is liable to practise masturbation; if in the next stage, he is likely to be homosexual. Fixation in the succeeding stage leads to an inconstant nature which is incapable of real attachment to one person, combined with an unnatural interest in self-display, which may vary from over-dressing to exhibitionism. Over-dressing in women is often caused by fixation at a corresponding stage. It is thus often the case that women who habitually paint and decorate themselves to an unusual degree are wholly without localized sex-feelings, because the unfolding of their sexual instinct has never arrived at the stage where these instincts are developed.

PERVERSIONS

Fixation is responsible for a great many cases of perverted sex instinct. Other perversions are caused by the exaggeration of one feature of the sex instinct perhaps to the exclusion of the rest of the instinct. Sadism and masochism are examples of this phenomenon. Sadism is the enjoyment of sexual pleasure in the infliction of pain

on the object of affection ; masochism is the enjoyment of having pain inflicted. It is a part of the normal masculine make-up to experience some pleasure in the feeling of over-mastery of the object of affection, just as to a normal woman there is pleasure in submission to this over-mastery. A horrible exaggeration of these harmless feelings leads to the vices of sadism and masochism respectively. Each of these vices may appear in either sex. There are other ways also in which a perverted sex instinct finds its consummation. In fetishism sexual desire is focussed on some part of the body or some garment which has no direct relation with normal intercourse.

COMPLEXES

Many perversions are due to what psychologists call "complexes." A complex arises when an instinct prompts one to do something which is contrary to one's nature. That such a situation has arisen may be completely forgotten, but its results appear as emotional or physical disturbances until all the circumstances which originated it are completely understood by the patient. When the disturbances are physical, as in nervous paralysis and nervous pains, there are usually no symptoms of anxiety. The reason is curious, and may be explained by an example. If anyone in the battlefield is very much frightened when ordered to advance upon the enemy, his fear instinct tells him to remain where he is or to run away, while his nature prompts him to advance. The strain thus caused may result simply in an anxiety symptom. But often the

promptings both of his instinct and of his personality are satisfied in a remarkable way: he finds that he cannot move, he is paralysed. Those who are paralysed in this way have great difficulty in believing that there is actually no physical reason why they should not walk. When all the circumstances which caused the phenomenon are disclosed by psycho-analysis, and he has lived through them again in imagination, the paralysis disappears.

Emotional and physical disturbances result commonly from complexes in which the sexual instinct is concerned. Extreme prudery, sexual frigidity, imagined pain in sexual intercourse are examples. A special case is the Œdipus complex. Here there is unnatural affection between mother and son, not appearing to the conscious mind as a sexual feeling but none the less adversely affecting the proper development of the sexual instinct of the son.

THE EQUALITY OF THE SEXES

The problem of the equality of the sexes is one of supreme difficulty, for it is almost impossible not to be prejudiced about it. Those who deny the difficulty of being unprejudiced, and who give their opinions on this subject with confidence, are least worthy of attention, for they have not realized the difficulties.

It appears to me that there are three questions to be answered, which are commonly confused:—

(1) In the existing state of society, are women inferior to men?

(2) Are women inherently inferior to men, or is their inferiority due to the circumstances of their environment ?

(3) Is it better that things should be as they are, or that women, if they are really man's equals, should be brought up as such ?

The opinions given below are open to correction as new facts are brought to light.

(1) In the existing state of society, women are on the average definitely inferior to men in nearly every sphere in which men care to compete. The few outstanding women prove this contention by reason of their fewness.

Even in what are supposed to be women's own spheres men are superior. If one wants the best possible cuisine, one engages a chef ; if a woman would have the most fashionable gown that money will buy, that gown is designed for her by a man. Women's inferiority is increased by the trifling courtesies which men perform for them.

(2) Mentally, there is very much less *inherent* difference between men and women than is apparent. Nearly all the mental differences between men and women are the result of upbringing. It is women's environment, particularly in childhood, that causes them to be inferior. From the earliest years they see women in an inferior position, and take it for granted. Before they can possibly know what sex means, they are given to understand that little girls are inferior to little boys, and cannot do the same exciting and original things. They are also taught to pay much more attention to their personal appearance than boys, and they see that all women do the same. They thus begin to allow their instincts of self-display to be used up in self-adornment, whereas little boys sublimate

the instinct in ways which are afterwards highly beneficial to the community. It is possible that nearly all the mental attributes which we consider as essentially male and female (as, for instance, aggressiveness in the male and coyness in the female) are not really inherent sex characters at all in mankind, or, if they are sex characters, at any rate they are not nearly such clearly-marked sex characters as we make them. It is quite probable that the only inherent mental differences between men and women are the instincts directly concerned with sexual intercourse and the care of children.

It must be remembered that in the past there have been civilized states in which the position of men and women was reversed. The women conducted the business and managed the state. They took part in athletic contests. They proposed marriage to the men. It was not only contrary to custom but actually an offence for a man to propose marriage. The men's business was to look pretty and wear beautiful clothes. Men were prostitutes for the pleasure of women.

(3) To most men the idea that women are their equals is abhorrent in the extreme, and they would greatly prefer that they should retain their present position. Many women would also probably prefer to remain as they are. But these opinions are probably not valuable. If these men and women had always, from earliest babyhood, lived in a state of society where the sexes were equal, and if they had never heard of a community in which women were inferior, it is almost certain that they would have disliked the idea of changing to the conditions of life of such a community. They cling to the present regime because

they have grown up considering it the right and proper one—indeed the only possible one ; and only very imaginative people can conceive, far less appreciate, the idea of a state of society quite different from that in which the whole of their existence has been passed. But a second motive causes women to cling to their present position. They have found it easier by far to give scope to their instincts in a direct way, not greatly to the benefit of society, than to sublimate them in a useful way.

In these facts we find, I think, the key to the answer of the third question. We should bring up girls in the same way as we bring up boys, and should not suggest to them any ideas of woman's inferiority. We should not encourage girls to be different from boys, because apart from the actual sexual instinct—which is as yet undeveloped—there is probably very little, if any, inherent difference between them.

It would be very hard for us, who have always lived in a state of society in which certain mental attributes are regarded as essentially male and others as essentially female, to throw over all these conceptions and start afresh. Indeed, I think that a sudden change in the state of society would not come about, even if it were a matter of common knowledge that our standards of masculinity and femininity were false ; for we should be unable, despite our better judgment, to accustom ourselves to such a change. So I think that it is incumbent on us gradually to educate each succeeding generation in a more rational way, until finally the desired equality of the sexes is reached without any annoyance to those who have been brought up to consider the present inequality natural and proper. It

should be noticed that I advocate equality of the sexes, not simply because I believe it to be the *natural* condition—for that is not a complete argument—but because I believe that instincts which are at present wholly used up in a direct and not very beneficial way could be sublimated to everyone's advantage if girls were educated, as boys are now, with less repression and with more encouragement to action and initiative.

CONTRACEPTION

A book on sex problems would be incomplete if no mention were made of a subject which is so much in the public eye just now as the contraception problem. The prevention of conception, popularly called "birth control," may be achieved in several ways. The usual methods are to kill the ejaculated sperms by weak poisons which are harmless to the tissues of the vagina, or to prevent the sperms from reaching the egg by placing a cap over the conical projection on which the opening from the vagina into the womb is situated. The practice of contraception has been strongly condemned, particularly by certain sections of the Church. The arguments used against it are partly ethical and partly pseudo-scientific. I will not deal at length with the ethical aspect of the question, because this book is scientific rather than moral. But I must point out that very few people are capable of giving an absolutely unprejudiced view on the ethics of sex, because nearly everyone has been educated in an atmosphere which associates sex with secrecy and immorality. Those who

pronounce contraception to be immoral are mostly people who, by the nature of their calling, are especially prejudiced. There are some, however, who object to contraception, not on ethical but on patriotic grounds, because, not having studied the problem, they consider (1) that a lower birth rate would result in a decreased population, and (2) that a decreased population would be deleterious. In their first contention they are wrong. In Holland, where contraception is practised more extensively than elsewhere, its effect has certainly been to reduce the birth rate; but the death rate has been so much decreased on account of the better care taken of children in small families, that the population has actually increased. Their second contention, the *raison d'être* for which is destroyed by the inaccuracy of their first, is almost certainly untrue. Many of the evils of life in Europe are caused by over-population. If, thanks to contraceptive methods, Great Britain were over-populated not by weaklings but by men and women who from the earliest moments of their lives—from the time when they were as yet unborn—had had the best possible conditions of existence, this over-population would be less demoralizing, for there would be more people whose sound constitutions and healthy minds fitted them for an agricultural life in our Dominions.

The argument that contraception is unnatural and therefore immoral is a curiously twisted rationalization. Nearly everything we do is "unnatural" in the sense that our remote ancestors in Pleistocene days did not do it. Those who preach the "natural" life are sometimes merely comic, as when they go off to the woods clad only

in underclothes, and sometimes extremely cruel and callous, as when they tried to prevent the use of anæsthetics in childbirth because it was unnatural.

The idea that contraception is immoral because any act is immoral if one is not prepared to take its consequences is self-contradictory ; for those who practise contraception do nothing the consequences of which they are unprepared to take. It would be absurd to say to a man, "It is immoral for you to step into that lift, because you are unprepared to take the consequences of its not being there."

The legal position in England with regard to contraceptives is that one is allowed to describe their use, to sell them, and to use them, but not to advertise them. One may advocate their use, but if one does so one incurs the risk of being libelled without the possibility of recovering damages. In the Land of Liberty and Prohibition it is a crime even to send instructions for the use of contraceptives in a sealed envelope by post.

Two main advantages accrue from a sensible use of contraceptives. Firstly, it is possible for people to live normal married lives without the enormous strain being put upon women of having continually to start to bear another child before they have properly recovered from their last pregnancy. For real health of mother and child, at least two years should intervene between one birth and the next. Many doctors consider five years a more proper interval. Secondly, from the child's point of view the advantages are enormous ; for except in well-to-do families the arrival of each child reduces the standard of living of the others. Throughout the animal kingdom we see

as a general rule that the most primitive animals have numerous young and look after them badly or not at all, while the most advanced have few young and devote their energies to their upbringing. The whole tendency of progress is towards the limitation of families and the better nourishment and education of the young.

Besides these two advantages, there are others of a more special nature. For instance, a woman's health may forbid her the possibility of bearing a child and surviving, but with contraceptives she is not prevented from living normally with her husband. Again, many newly-married people who are as yet without proper accommodation for the upbringing of a child may advantageously wait until they are more suitably housed.

It is reassuring to find that there are not very many well-educated people nowadays, except those whose minds are made up for them by the authorities of their religion, who oppose the practice of contraception. It is unfortunate that the voice of those who are opposed to contraception is a disproportionately loud one, owing to the reactionary nature of the greater part of our daily press.

CONCLUSION

Most animals have a breeding season, and traces of it remain in mankind. The most primitive animals merely shed their sperms and eggs into the sea ; in higher animals copulation prevents the great waste of material which this involves. Often, especially in birds, some form of courtship is enacted preparatory to copulation. Often a pair

of animals, male and female, associate together for the breeding season or longer; in other cases one male associates with several females. Mankind is for the most part polygynous or monogamous; polyandry is rare. Primitive man probably practised group marriage.

The sexual instinct may advantageously be sublimated if reasonably checked. Sexual perversion may be caused by fixation, by exaggeration of one part of the sexual instinct, or by complexes.

Women are probably not inherently inferior to men; their inferiority is due to their upbringing, during which inferiority is continually (though unintentionally) suggested to them.

Contraception offers better health to women, better nourishment and education to children, and a normal sexual life to many who would otherwise be denied it.

END

A LIST OF BOOKS DEALING WITH SEX PROBLEMS.

The study of sex problems is proceeding so rapidly that one can only keep pace by reading the various scientific journals. The most important facts and theories can, however, be gathered from the books listed below.

- BOUSFIELD, P. *Sex and Civilisation*. Kegan Paul & Co.
 CARR-SAUNDERS, A. M. *The Population Problem*. Oxford University Press.
 CHAMPY, CH. *Les Caractères Sexuels*. Octave Doin, Paris.
 CODRINGTON, R. H. *The Melanesians*. Clarendon Press.
 DARWIN, C. *The Descent of Man and Selection in Relation to Sex*. Part II. John Murray.
 DONCASTER, L. *The Determination of Sex*. Cambridge University Press.
 ELLIS, HAVELOCK. *Studies in the Psychology of Sex*. F. A. Davis Co.
 GEDDES, P. AND THOMSON, J. A. *The Evolution of Sex*. Walter Scott.
 GOLDSCHMIDT, R. *The Mechanism and Physiology of Sex Determination*. Methuen.
 *GOODRICH, E. S. *Living Organisms*. Clarendon Press.
 HADFIELD, J. A. *Psychology and Morals*. Methuen.
 HAMMOND, J. *Reproduction in the Rabbit*. Oliver and Boyd, Edinburgh.
 HUXLEY, J. S. *Essays of a Biologist*. Chap. 4. Chatto and Windus.
 LIPSCHÜTZ. *The Internal Secretions of the Sex Glands*. Heffer, Cambridge.
 MORGAN, T. H. *Heredity and Sex*. Columbia University Press.
 PYCRAFT, W. P. *The Courtship of Animals*. Hutchinson.
 RIVERS, W. H. R. *Social Organization*. Kegan Paul and Co.
 STOPES, M. C. *Contraception*. John Bale, Sons and Danielsson Ltd.
 WALLACE, A. R. *Darwinism*. Chap. 10. Macmillan & Co.

* Recommended as a general instruction to Biology.

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